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ON THE RELATIONS OF STELLAR ELECTRICITY AND MAGNETISM TO THE PHENOMENA OF THE SUN'S ATMOSPHERE[1]

By Dr. ROSS GUNN

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NEARLY twenty years ago Hale and his collaborators at the Mt. Wilson Observatory established the existence of a general solar magnetic field. Measurements of the Zeeman displacement of certain spectroscopic lines showed that the solar magnetic field is quite large and that the sign and distribution of the field at given levels were strikingly similar to that of the earth. An unexpected anomaly was found, however, in the very rapid radial decrease of the magnetic field, which dropped from 55 gauss at an altitude of 250 km to about 10 gauss at 450 km. The observed data are consistent with the conclusion that the sun is a uniformly magnetized sphere whose axis is tipped about 6° to the axis of spin and completely surrounded by an atmosphere which somehow limits the external magnetic field by systems of electric currents. Fig. 1 illustrates in a rough manner the presumed distribution of the magnetic field within and around the sun, while Fig. 2 gives the observed magnetic field intensities in the sun's atmosphere as a function of the altitude above the photosphere.

It is well established that the pressure in the solar atmosphere, at levels that may be observed, is well below one one-hundredth of an atmosphere and that the molecules are nearly all ionized. That is to say, the solar atmosphere is a rarefied ionic gas with an

[1] An address delivered before the Section of Astronomy, American Association for the Advancement of Science, Syracuse, New York, on June 21, 1932.

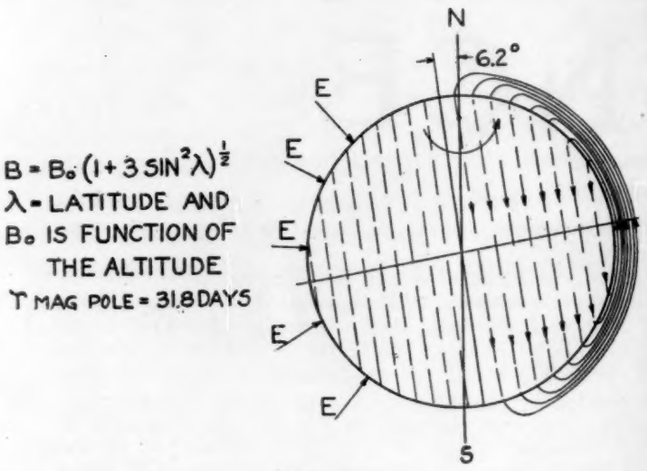

FIG. 1

admixture of neutral atoms, all immersed in a magnetic field. In an early paper we studied the effects that would be produced in a rarefied ion gas in which the ions execute long free paths as a result of thermal agitation in a magnetic field. In Fig. 3, consider an ion having a charge e that suffers a collision and starts off on its free path in a magnetic field B with a velocity v_o. The ion will be acted on by a magnetic force Bev_o, which is always at right angles to the instantaneous velocity, and this just balances the centrifugal force; hence the ion is constrained to spiral around the magnetic field. Now, the spiralling ion of mass m is equivalent to a small magnet of magnetic moment $mv_o^2/2B$ and its field is always opposed to the impressed magnetic field B, irrespective of the sign of the charge or its initial velocity. If there are N ions per unit volume, then the intensity of magnetization of the region is

$$I = -\frac{NkT}{B\left[1+\left(\frac{R}{\lambda}\right)^2\right]}$$

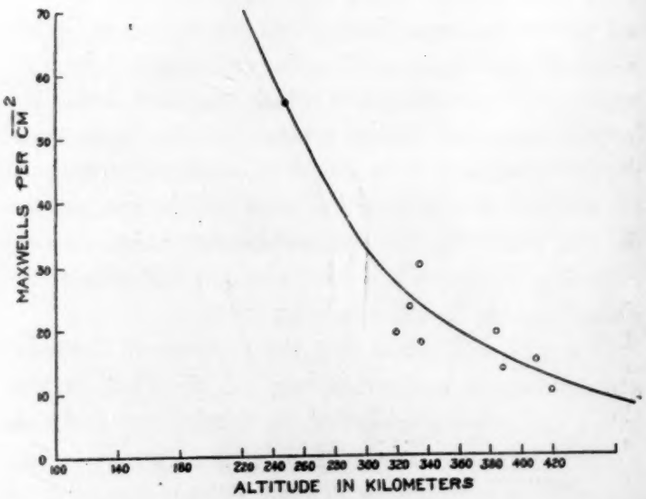

FIG. 2

and the approximate permeability of the medium is

$$\mu = \frac{1}{1+\frac{4\pi N k T}{B^2\left[1+\left(\frac{R}{\lambda}\right)^2\right]}}$$

where k is the Boltzmann constant, T the temperature of the region, R the radius of the generated helix and λ the mean free path. It is evident from these relations that the permeability of the sun's atmosphere must be less than unity—that is, the sun's atmosphere is diamagnetic. We may calculate the permeability from the approximately known ion pressures, or we may suppose that the limitation of the sun's magnetic field is due to diamagnetism and calculate the ion pressures, and compare these with observation. We here adopt the latter procedure and note that, if the observed limitation is due to diamagnetism, the permeability of the atmosphere must depart markedly

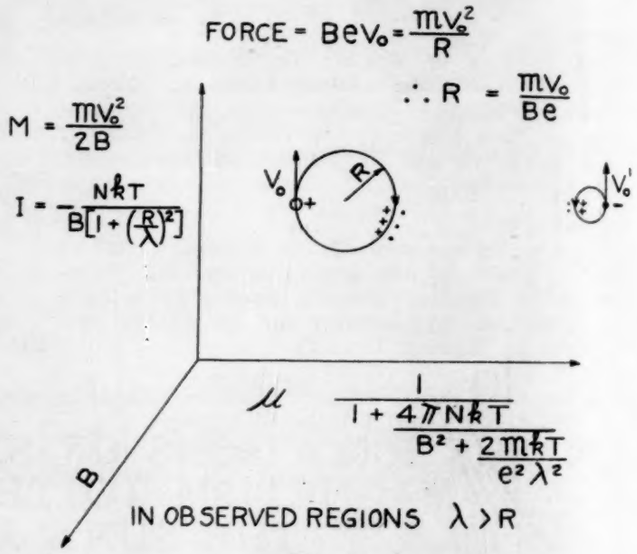

FIG. 3

from unity. We assume as a first approximation that the permeability is ½ and calculate the ionic densities in terms of the observed values of B. We have plotted in Fig. 4 the ion densities as a function of the altitude, and, if we assume this represents an atmosphere in gravitational equilibrium, we find that its mean atomic weight is 3.3. These values are in fair agreement with later determinations by other methods. We see, therefore, that diamagnetism in the sun's atmosphere so distorts the general magnetic field that it becomes nearly tangential to the solar surface at all points except near the poles and thereby brings about the observed limitation of the field.

For nearly a century it has been known that the rotation of the sun was anomalous and that the equatorial period of rotation is considerably less than that at the pole. From the great mass of data which have been compiled, there appears to be little doubt that

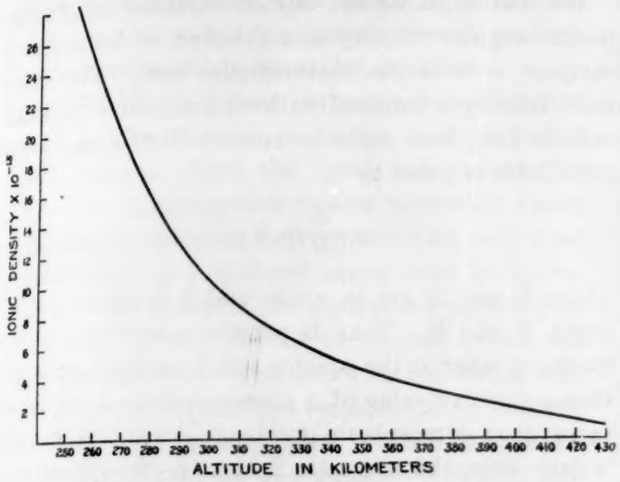

FIG. 4

not only does the rotational period change with latitude and altitude but it also changes with time. We have reproduced in Fig. 5, St. John's plot of the peripheral velocity of the sun and have indicated by the dotted curve the expected distribution if the sun rotated like a rigid body with a period of 31.8 days. The upper curve was plotted from data taken about 1907 and the next lower one about 1920. The variation of the rotational period with time and sunspot activity is shown in Fig. 6. It is to be noted that the amplitude of the fluctuation is some 8 per cent. of the total and is many times the probable error. Newall and Hahm believe that the sun rotates fastest at sunspot maximum, but their conclusion is only indifferently supported by St. John's data.

Study of the sun's rotation shows that the period depends slightly upon the object selected for observation and that the speed increases slightly with increasing altitude above the photosphere. In addition to these systematic changes there are many local variations and it is well known that even a single sunspot does not rotate at a constant speed.

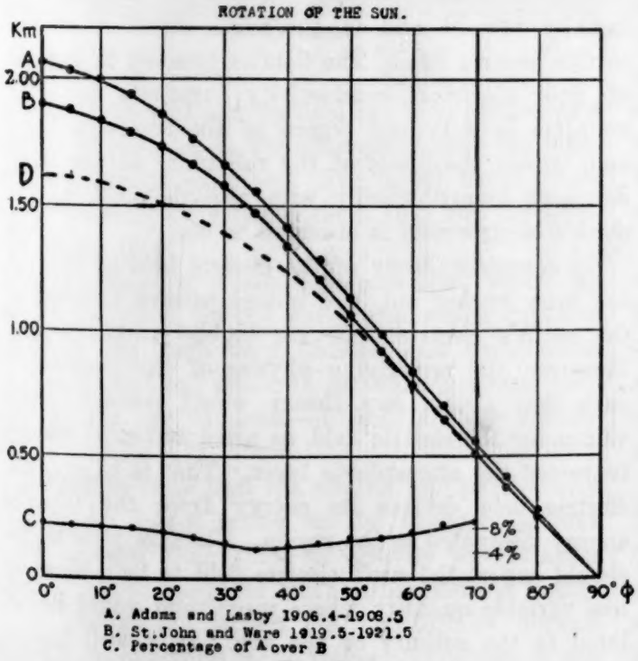

FIG. 5

Purely mechanical effects could hardly account for these observed motions, since a periodic change in the period of rotation would involve a periodic change in the moment of inertia of the sun. This seems highly improbable, and if such a change did take place it could not account for the observed rotation of the chromosphere faster than the lower layers. Moreover, even if we should deny the reality of the time variation and adopt Jeans' account of the variation of velocity with latitude, we are still faced with great difficulties. Jeans' postulated rapid rotation of the sun's core is inconsistent with observed magnetic data because the magnetic pole of the sun does not coincide with its axis of rotation but rotates around it once in

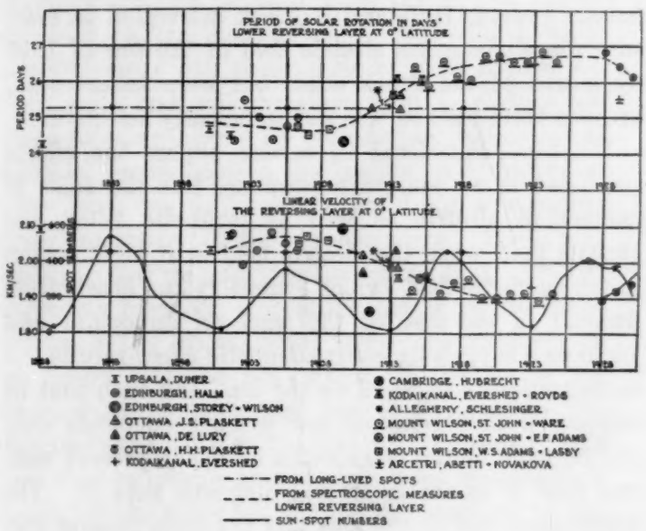

FIG. 6

31.8 days. This suggests that the sun is semi-rigid, since, if the angular velocity should increase inward, the relative motion of the highly conducting layers and the magnetic field will set up tremendous systems of electrical eddy currents which will damp out very rapidly any relative motion, the mechanism being precisely that of the classical experiment of elementary physics in which a massive copper pendulum is swung between the poles of an electromagnet.

The presence of the sun's magnetic field and its known asymmetry seems to assure us that the sun, like the earth, rotates essentially as a rigid body carrying its magnetic pole around with it once a revolution. We adopt this conclusion as a postulate. It then follows that the period of rotation of the sun proper and its associated magnetic pole is 31.8 days and is an invariable quantity. It also follows from observation that the sun's atmosphere is in motion and it rotates faster than the sun proper. That is to

say, a high velocity superposed wind blows constantly to the eastward. In Fig. 5 the dotted curve shows how the surface velocity of the sun proper must change with latitude if it is quasi-rigid. The difference between the observed curves and the dotted one evidently represents the superposed atmospheric velocity, and this approximates 0.5 km/sec at the equator.

How may such a systematic motion of the atmosphere be maintained and what will be the consequences of such a motion? Evidently no simple mechanical mechanism would account for a systematic eastward motion; but our investigations suggest that the motion is a necessary consequence of electric fields in the sun's atmosphere as well as the observed magnetic field. Now it is known that the earth possesses a radially inward electric field which is greatest in regions of poor electrical conductivity, and it is perhaps reasonable to expect analogous solar electrical fields. Indeed, Hale and Babcock attempted to measure the atmospheric electric field of the sun in 1915 by means of the Stark effect but were unsuccessful because their method was not sufficiently sensitive.

We have considered in earlier papers the effects produced in an ionized atmosphere like the sun's if subject to electric as well as magnetic fields and showed that, when the electric field is at right angles to the magnetic field (which symmetry and observation demand in the case of the sun) an important and perhaps a surprising electromagnetic effect results. A mass motion is imposed on the ion bank such that its velocity u in regions of low pressure depends only on the ratio of the magnitudes of the impressed electric field E to the impressed magnetic field B. The paths described by the ions and the more general vector expression for the magnitude of the superposed mass velocity, which we will refer to as an electromagnetic wind, are given in Fig. 7. The magnitude

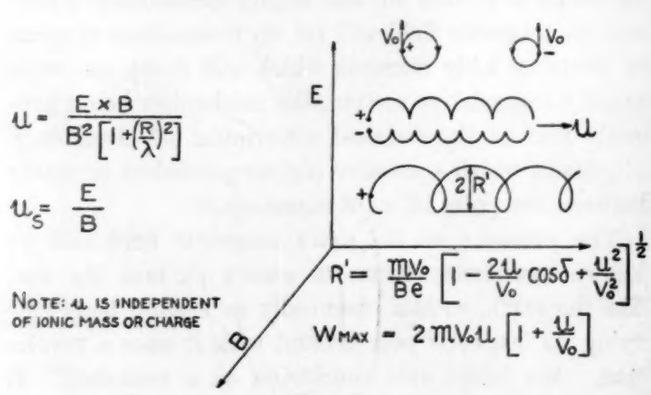

FIG. 7

of B is known in most of the reversing layer, and, by the use of the calculated values for u derived from direct observations, we can readily calculate the electric fields that must exist in the sun.

We first calculate the law of variation of the apparent angular velocity as a function of latitude and compare it with the observational data. The mean drift velocity u imposed on both kinds of ions which execute long free paths in crossed electric and magnetic fields is given by

$$u = \frac{E}{B}\sin\beta$$

where E and B are in e.m.u. and β is the angle between E and B. Take B positive northward in the reversing layer at the equator and E radially outward, then a positive value of u corresponds to a westward superposed atmospheric motion. According to Mt. Wilson data, the magnetic field at a given level and latitude λ is given by

$$B = B_o\,(1+3\sin^2\lambda)^{\frac{1}{2}}$$

where B_o is the value of the equatorial field at the level considered. Thus combining the foregoing relations, the superposed angular velocity of drift is

$$W = \frac{E\sin\beta}{B_o R_o\left[(1+3\sin^2\lambda)\,(1-\sin^2\lambda)\right]^{\frac{1}{2}}}$$

where R_o is the radius of the sun. The magnetic and electric fields are virtually at right angles throughout the region of observed data so that we may set $\sin\beta = -1$, and for not too large values of λ; the last equation may be expanded to

$$\Omega = \Omega_o - (E/B_oR_o)\,(1-\sin^2\lambda)$$

and this agrees with the observed form of the variation of angular velocity with latitude. Putting in the correct constants and carrying through the calculations, we find that the required electric field is radially inward and in the same direction as the earth's electric field. The field is greatest in regions of poor electrical conductivity; amounts to 0.013 volts/cm in a typical region of the reversing layer and, within the limits of the reliability of our data, decreases logarithmically with altitude much as the earth's electric field is observed to do.

No complete theory of the electric field of the sun has been worked out, and indeed present theories of the earth's electric field are highly unsatisfactory. However, the underlying physics of the problem is such that almost any theory would predict larger values for the electric field, as more and more energy traversed the atmospheric layer. That is to say, the electric field derives its energy from the thermal energy dissipated in the region. Thus, in general, we should expect the sun's electric field to be a more or less variable quantity whose magnitude would be related to the activity of the sun. It is well known that the sun is a variable star of small range, and our

examination of electromagnetic effects in its atmosphere shows that radiation changes should produce, indirectly, changes in its apparent rotation.

Magnetic fields of the sun have not been measured above 500 km, but there is no reason to suppose that the field vanishes above this level and, indeed, the fact that the chromosphere rotates somewhat faster than the upper reversing layer guarantees that some such mechanism as considered above must be operative. The observations of the superposed motion give only the ratio of the electric to magnetic field and indicate that this ratio increases with increasing altitude until coronal regions are reached. Even in these regions there is evidence of faster rotation than in the chromosphere, so that we may suppose that here also the ion pressures and field intensities permit the existence of electromagnetic winds. It may be seen, therefore, that we can account for substantially all the observed features of the anomalous rotation of the sun if we grant that the sun has an atmospheric electric field not unlike the electric field of the earth. In

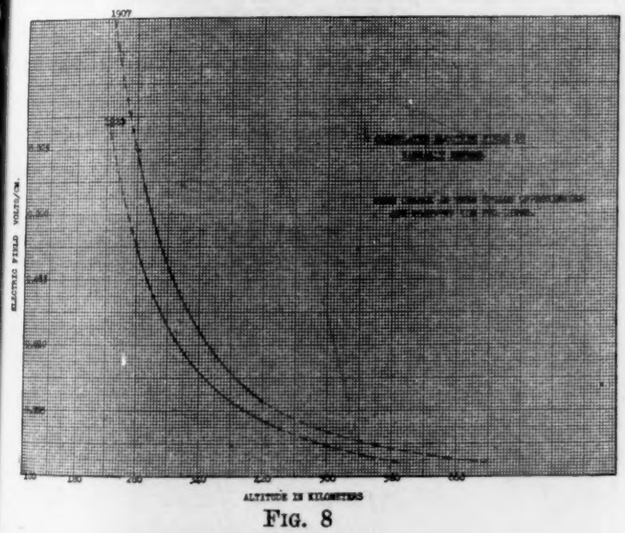

FIG. 8

Fig. 8 the estimated electric field has been plotted as a function of altitude on the assumption that the magnetic field remains constant. The upper curve corresponds to conditions existing about 1907 and the lower curve about 1920.

The existence of a simple mechanism, which we know is operative on the earth and which explains completely the sun's very unusual and complicated atmospheric motion, seems to establish a strong presumption for the existence of such a solar electric field.

Calculations show that the electric and particularly the magnetic forces acting on the atmospheric ions are far greater than those of gravity or radiation pressure. Thus, since the sun's atmosphere is highly ionized, we should expect its stability to depend primarily on electromagnetic forces. However, in the solar atmosphere we must recognize two highly differentiated types of particles acted on by forces of quite different magnitudes. The neutral atoms are acted on only by gravitation and radiation pressure so that they are free to diffuse where they will, and thermal processes will cause great numbers of them to be shot to high altitudes of low pressure where their chance of becoming ionized is increased tremendously. Once the particles are ionized the forces acting on them are increased hundreds of times and they are constrained to spiral around the impressed magnetic field and advance to the eastward as a result of their interaction with the electric field. When the ion recombines to form a neutral atom, it is again free to be acted on by gravity and it may fall to low levels. A single atom will spend some of its time in the ionized state and some in the neutral state. In general, we may expect to find particles which spend a very large fraction of their total life in the ionized state, high in the chromosphere, while those which recombine easily will spend most of their time in the neutral state and will therefore drop to regions low in the reversing layer. By considering the ionization potentials, recombination coefficients and masses of all the ions, we could easily build up a complete equilibrium theory of the chromosphere. These data are lacking and we only point out here, that, although the electric force on a positive ion is in the same direction as the gravitational force and hundreds of times larger, yet the net motion of the ion is not downward but is tangential and to the surface and moves eastward. Thus, the ion is "supported" and we see that magnetic and electric fields qualitatively account for the observed motion and stability of the sun's atmosphere. On the basis of such a theory we need not be surprised to find the arc spectra of a given element as well as the spark spectra at high levels; for there is no reason to suppose that a captured neutralizing electron will go to its lowest energy level immediately, but it may just as readily drop by steps, yielding the spectrum of a neutral atom.

It is, perhaps, of interest to note also that stability of the type we have considered would be little disturbed if the star rotated so fast on its axis that its surface acceleration approached zero. Thus, since some rapidly rotating nearly unstable stars are observed to retain their atmosphere, we infer that magnetic fields must be a common property of stars.

Several writers have studied the solar radiation and found it to depart markedly from black body radiation. Eddington, in his reexamination of the available data, estimated the sun's effective temperature as calculated from the density of radiation to be 4660°, while the temperature corresponding to the quality

of the received radiation is 1080° higher or 5740°. Thus the solar radiation is far richer in the high energy region of the spectrum than the total received radiation would lead us to expect. It is well known, also, that the emission spectra of hydrogen and helium are strong in eclipse spectra and we are led to inquire if these phenomena are not directly related to the sun's electric field.

We encounter a serious handicap at the start of our investigation, for, if appreciable electric fields actually exist in the sun's atmosphere, then it can never be in thermodynamic equilibrium and we have no right to use the powerful thermodynamic method developed by Saha to determine the state of ionization or excitation of the solar atoms. This complicates the problems we face, because we have then to work out the detailed processes of excitation and ionization. This has been done only for one or two simple cases so that for the present we must be content with a purely qualitative description of the effects.

Although it is probably not permissible to use equations based upon thermodynamic equilibrium in the sun's atmosphere, many investigators have done so. They find, for example, by these methods that, in the case of hydrogen, the calculated numbers of atoms that must be in a state to account for the H_α line must be increased by a factor of 800 if it is to agree with the number calculated from the observed line contours, whereas the numbers for H_δ must be multiplied by 25,000. From the form of the relations we can see that the discrepancy between the observed and calculated number will increase as the ionization and excitation potentials of the selected state increase. Thus, we find in the case of the line λ4686 of ionized helium that the calculated numbers of atoms in the required state must be multiplied by a factor something like 10^{40} to represent correctly the observed abundance. It is clear that something is seriously wrong with the methods employed. Dr. Menzel, of the Lick Observatory, notes that most of the difficulties can be resolved if, in the modified Saha relations, we insert a value of 18,000° for the solar temperature. There is some evidence for believing that such temperatures may exist in localized regions, but it could hardly exist generally throughout the sun's atmosphere. Thus we are forced by the observational data to believe that the mean temperature of the sun does not depart greatly from 5,000°, yet that some auxiliary mechanism is operative in its atmosphere which produces excitation and ionization corresponding to far higher temperatures. This is about the situation that we would expect to exist were the solar atmosphere permeated by electric fields of the calculated magnitude.

One might suppose that an ion describing a free path in an electric field would gain energy proportional to the product of the electric field and the length of the free path; but in the presence of a magnetic field this is not the case, as the ion is constrained to describe a curved cycloidal path. The lower curve of Fig. 7 shows the trajectory of a typical ion. It is clear that the maximum distance that the ion can travel in the direction of the electric field is $2\,R^1$, where R^1 is specified by the equation in Fig. 7 and hence the maximum energy W_m that can be added to or subtracted from a typical ion by the impressed electric field even if the free path is infinitely long is given by

$$W_{max} = 2\,m\,V_o\,u\,(1+\frac{u}{V_o})$$

in which m is the mass of the ion, v_o is its initial velocity and $u = E/B$. Thus in the sun's atmosphere we have substantial equipartition for the neutral molecules, whereas the ions take on and lose successively energies specified by the foregoing relation. We note that the excess or deficiency of energy depends on the mass of the ion and calculate that the electric field does not particularly disturb the energy distribution of the electrons but does greatly modify the energies of the ions. In Fig. 9 we have plotted

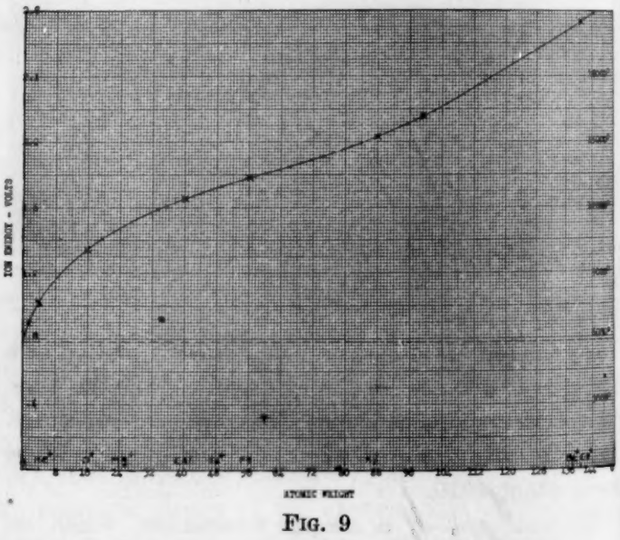

FIG. 9

the maximum energies of ions of different atomic weights on the assumption that the initial velocity of the ion is the mean thermal velocity and that the electric field has the values just calculated. After some collisions special ions will start off with an even higher velocity and a small but finite number of the particles will have their maximum energy increased by perhaps more than twice that indicated by the curve. The energies have been expressed both in electron volts and in terms of the temperature that ions of the same

energy would be in thermal equilibrium. Thus in the solar atmosphere we have an ionized gas which is in anything but thermodynamic equilibrium. Many ions have very low energies and absorb energy readily, while some have very high energies that can be passed on by collision and produce abnormal excitation in other atoms. For example, the maximum energy of a calcium ion is as great as it would be if it were in thermal equilibrium at 12,000° while a barium ion would approximate 20,000°. We note particularly that the energy of an ion changes continuously during its flight and its energy at collision depends on its position and trajectory. The neutral atoms and electrons are not particularly disturbed by the electric fields and except for their collision with ions of excessive energy, they would approach an approximate thermodynamic equilibrium. The problem of working out the detailed equations of equilibrium between excitation and deexcitation of all the different kinds of ions in the solar atmosphere is an imposing one and will probably not be solved for some time. It does appear, however, that electric fields in the solar atmosphere will account qualitatively for the observed anomalous characteristics of the sun's radiation, because such fields make possible the selective excitation of the more energetic radiations without disturbing in any important manner the mechanisms which are responsible for the general radiation.

Our studies of the relations of electricity and magnetism to the properties of the sun's atmosphere have demonstrated that electric and magnetic effects play, perhaps, a major rôle in determining the observed phenomena. While it can not be said to be proved beyond doubt that electric fields exist in the sun's atmosphere, yet the internal evidence and the interrelation of much data makes the existence of such fields seem probable. Much additional data are needed to completely test our results, and it is sincerely hoped that the solar eclipse of 1932 will be of material aid in this respect.

ON THE LOCOMOTION OF SNAKES[1]

By Dr. WALTER MOSAUER

UNIVERSITY OF CALIFORNIA AT LOS ANGELES

DURING the years 1929–1931 an investigation dealing with ophidian locomotion and its anatomical basis was carried on in the Department of Anatomy, University of Michigan. Since the publication of the voluminous thesis embodying the results of this work has met with considerable delay, it seems advisable to publish a brief abstract at this time.

The anatomical structures involved in locomotion are the skeleton of the trunk and tail, their musculature and integument. All three show special modifications fitting them for their task.

The vertebral column of a snake consists of a very great number of single pieces, sometimes as many as several hundred; each vertebra articulates with a neighboring one at five points. The shape of the articulating surfaces restricts the possible movements to two main planes, *i.e.*, to the frontal plane, permitting of lateral flexion, and to the sagittal plane, permitting of dorsal and ventral flexion. Moreover, movements in both planes can be so combined as to allow the snake the multitude of graceful windings that makes the ophidian vertebral column the most remarkable instance of mobility in this organ, although rotation about the long axis is wholly impossible. X-ray photographs were used to determine the degree of flexibility in the main planes; it was found in several different species to be about 25° for lateral flexion between successive vertebrae, about 13° for ventral flexion, while the maximum of dorsal flexion varied from 12° to 18°. The ophidian vertebral column, considered as a mechanical unit, is of an admirable perfection. It permits of almost unrestricted movements in the frontal and sagittal plane, avoiding any loss of energy in the production of these movements by the impossibility of rotation. Moreover, it is very resistant to strain and stress in the long axis, thus making for high efficiency in transferring the locomotor forces from one small section of the body to the whole.

Each vertebra from the second to the last trunk vertebra articulates with two ribs that are attached to it by clublike enlarged extremities, while their other ends are free between the muscle sheets. The vertebrocostal articulation, while it was generally considered as a ball and socket joint, actually functions as a hinge joint, a ginglymus, in which movements are possible in one oblique plane only, due to the peculiar shape of the articulating surfaces. Consequently, the free end of a rib when moved forward is also lifted; when moved backward, it is depressed. This seems to be of significance in locomotion.

The myology of the body of snakes is at the same time simple and complicated. It is simple because, due to the loss of the extremities, the appendicular muscles have disappeared, except for a few rudiments.

[1] Abstract of a lecture delivered before the Western Society of Naturalists, Berkeley, California, December, 1931.

Thus the musculature of the body is formed by a repetition of segmental muscles throughout its length, not overlapped by extremital muscles. On the other hand, the myology is complicated, because the remaining system is highly specialized.

The skeleton of the trunk is made up of vertebrae and ribs; therefore, we can distinguish principally three main groups of skeletal muscles: (1) Muscles between vertebra and vertebra, (2) between vertebra and rib and (3) between rib and rib. A fourth group of muscles connects the ribs to the integument, and finally there are cutaneous muscles connecting parts of the integument to each other, *i.e.*, scales to scales.

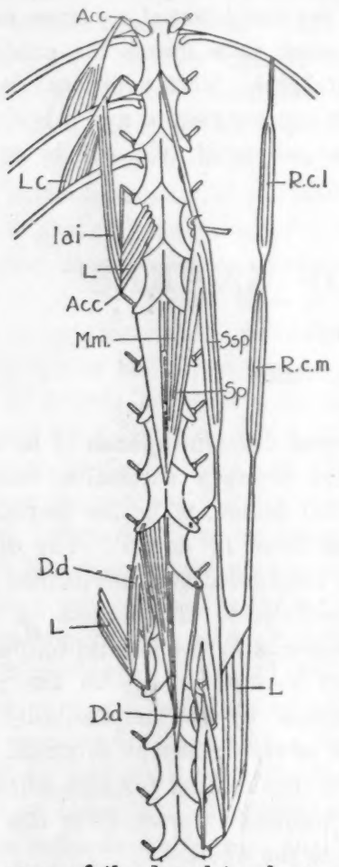

FIG. 1. Diagram of the dorsal trunk musculature of a racer, showing the linking of the long muscles to chains.

All these muscles are strictly segmental, as can be shown by careful dissection, but the individual segments of some of them are very much elongated. This specialization has reached the extreme in the Colubridae, especially in the slender racers; here some of the muscles are linked together so that they extend over more than 30 vertebrae without attachment. The purpose of this is apparently to permit an equal bending over a considerable length of the vertebral column. If the muscles were to stretch over a few segments only, the synchronous and equal flexure would not be as well insured as by very long muscles overlapping each other by one segment only.

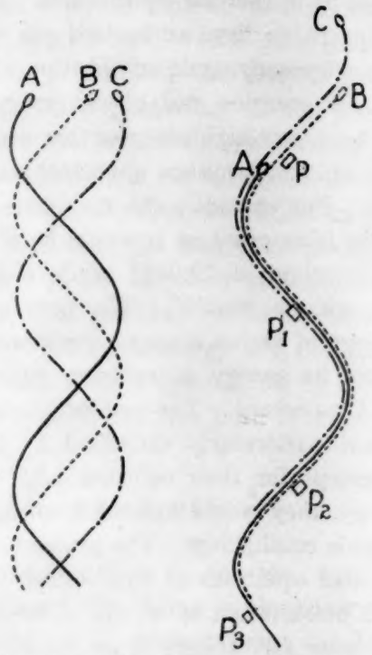

FIG 2. Diagrams of a snake during horizontal undulatory movement in three phases A, B, C. I. on a glass plate, II. on ground offering circumscribed points of resistance P, P_1, P_2, P_3.

A detailed comparative study of the trunk musculature of over 50 genera showed significant differences between the taxonomic main groups, differences that could well be used for determining relationships and phylogeny of the snakes.[2]

The specialization of the integument serving locomotion consists in the formation of the broad, imbricating transverse scutes on the ventral surface, replacing the smaller scales of the flanks and the back.

Locomotion of terrestrial snakes is performed by three principal methods: the horizontal undulatory

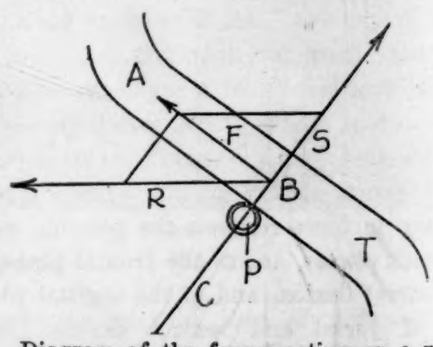

FIG. 3. Diagram of the forces acting on a portion B of a snake's body during horizontal undulatory movement. B is pressed to the left by the force R, S is the reaction of the point of resistance P on the pressing portion, the reaction being normal to the surface as in sliding bodies. F, the resultant of R and S causes the progression along the longitudinal axis AT.

[2] Presented under the title, "The Trunk Muscles of Snakes and Their Bearing on Phylogeny and Taxonomy," before the American Society of Zoologists, Cleveland, Ohio, December 1930.

movement, the sidewinding or rolling movement and the caterpillar movement. The first one is the typical serpentine wriggling, the method used by most snakes for rapid locomotion. It is produced by the progression of transverse waves over the body of the snake from the head to the tail, principally like the movements of many aquatic animals in water. These transverse waves result in the displacement of each point of the snake's length in a direction approximately normal to the direction of locomotion, if there is no lateral resistance, as on a glass plate, where because of the side slippage, the snake's wriggling is futile, not resulting in progression. Under natural conditions the ground always furnishes points of resistance in the form of rocks or pebbles, the stems of plants or simply small unevennesses. The snake uses

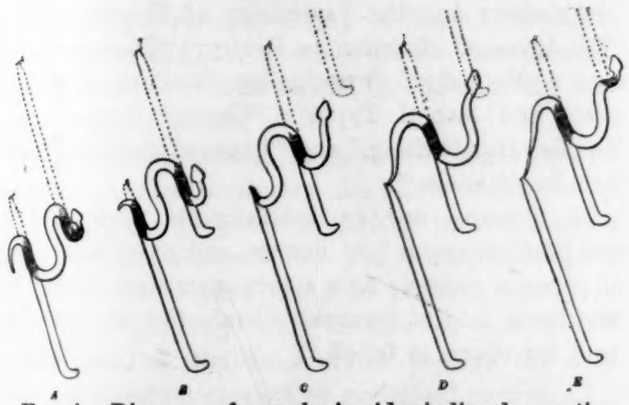

FIG. 4. Diagram of a snake in sidewinding locomotion, representing 5 phases. Only the shaded parts of the snake touch the ground. The formation of parallel, oblique, disconnected tracks is shown.

these points of resistance by applying its curves to them, whereby mainly the body portions midway between two successive vertices are pressed against the projections of the ground. Then any side slippage is avoided by the half cylindrical shape of the body and especially by the sharp keels present in many snakes along the flanks. Every point of the snake's body and tail faithfully follows the path taken by the head and neck, so that the snake seems to flow gracefully through grass and shrubs like a water course in its narrow, winding bed. The diagram Fig. 3 shows how the forces brought about by the horizontal undulations are transformed into progress in the longitudinal axis. The main work is done at the points midway between two vertices of the sinuous curve; here the forces are greatest, gradually decreasing towards the vertices, where they may be zero. The ventral scales are of no use in the horizontal undulatory movement.

The sidewinding or rolling movement is applied by viperide snakes inhabiting sand deserts, namely, the members of the genus *Cerastes* in the Sahara and the "Sidewinder" (*Crotalus cerastes*) in the southwestern deserts of the United States This progress is principally like the sidewise rolling of a circular helix or screw—the tracks left by a wire helix being, like those of a sidewinding snake, a series of disconnected equidistant and parallel bands, set at an angle to the direction of motion, each as long as the helix (or snake, respectively). The advantage of this type for the sandy habitat consists in its not requiring any resistance or reactions of the substratum, except that the latter has to carry the weight of the snake.

The caterpillar movement is the one method in which the ventral scales play that important rôle which was formerly attributed to them for snake locomotion in general. It consists of an alternate movement of the skin on the body and of the latter within its tube of skin. First the skin is pulled forward, then it is anchored on the ground, whereby the ventral scales catch points of resistance, and the body is pulled forward until the corresponding portions of integument and body are in touch again. The ribs are not employed in the sense of the "rib walking" theory maintained by former authors. The movement described proceeds rhythmically from the head tailward. By this method a snake can glide slowly forward, stretched out fully or slightly undulating. The caterpillar movement is applied mostly by thick-bodied snakes like Boidae and Viperidae, *e.g.*, rattle snakes. Finally, snakes can move by alternately bending and straightening portions of their bodies. Speed-testing experiments with the famed "Blue Racer" have shown that the apparent rapidity of many snakes is a psychological delusion rather than actual speed in meters per second. However, more extensive tests along this line are desirable.

The author is at present engaged in an investigation dealing with the locomotion and the locomotor adaptations of sand reptiles.

OBITUARY

JUNE ETTA DOWNEY

THE University of Wyoming lost its most distinguished scientist when Dr. June Etta Downey, professor of philosophy and psychology, died on October 11, 1932. Dr. Downey was born in Laramie, Wyoming, on July 13, 1875, and resided there throughout life. Her researches in the fields of handwriting, imagery, "will-temperament" testing, handedness and esthetics earned for her international recognition.

Dr. Downey was graduated from the University of

Wyoming in 1895. Her early interests were artistic and literary. As an undergraduate and during the first few years of her teaching, she was introduced to many of the concepts of natural science by the late Dr. Edwin E. Slosson, who was professor of chemistry at the University of Wyoming from 1891 until 1904.

In 1898 Dr. Downey received the A.M. degree from the University of Chicago. The summer of 1901 was spent in the laboratory of Edward Bradford Titchener at Cornell University. She returned to the University of Chicago in 1906, and a year later received the Ph.D. degree upon the completion of her dissertation, "Control Processes in Modified Handwriting." Her graduate work was done under the direction of Dr. James Rowland Angell.

Dr. Downey was more interested in motor responses than in sensory phenomena. Her interest in handwriting persisted throughout life. Muscle reading engaged her attention about 1908. She noted personality differences that she described under such trait names as "freedom from inertia," "motor impulsion," "motor inhibition," "reaction to opposition," etc.

For ten years Dr. Downey experimented with handwriting procedures and ingenious test situations that would indicate the personality differences which she recognized. In 1919 she presented her test results in a bulletin, "The Will-Profile: A Tentative Scale for Measurement of the Volitional Pattern." The Individual Will-Temperament Test represented a pioneer effort to measure three aspects of personality: (a) the fluidic, speedy, "hair-trigger" type of response, (b) the dynamic, aggressive, forceful type, and (c) the slow, deliberate, inhibited type. Instead of a total score, Dr. Downey advocated the plotting of a graph, or "will-profile," to show the differences in the personality make-up of an individual. She viewed personality as an integrated whole, and reacted against the tendency to abstract a trait from its setting. Her pioneer work has stimulated a vast amount of research in the field of personality evaluation.

The best-known books and monographs of Dr. Downey include "The Will-Temperament and Its Testing;" "Creative Imagination;" "The Kingdom of the Mind;" "The Heavenly Dykes," (a volume of poems); "Plots and Personalities" (with E. E. Slosson); "Graphology and the Psychology of Handwriting;" "The Imaginal Reaction to Poetry;" "Muscle Reading: A Method of Investigating Involuntary Movements and Mental Types"; "Control Processes in Modified Handwriting," and "Types of Dextrality and their Implications."

Dr. Downey was an indefatigable worker. She was kind, generous and human, and never lost sight of personal values. As a steady, persistent worker in her chosen field of personality evaluation she blazed a trail for others to follow.

R. S. UHRBROCK

SCIENTIFIC EVENTS

EXTENSION OF THE PLYMOUTH MARINE BIOLOGICAL LABORATORY

IN the past, investigations carried on at the Marine Biological Laboratory at Plymouth, England, have been chiefly devoted to morphological and fisheries research. Emphasis has been placed upon the latter because of the fact that the station has been subsidized by the national government and by commercial organizations, both of which were of course interested in "practical" results. Nevertheless, there is a growing number of physiologists and ecologists who work regularly at Plymouth, and it is the intention of the directors to further increase the scope and facilities of the laboratory.

During the past summer (1932), an addition to that part of the buildings known as the "new wings"[1] was completed. This latest portion, built with the aid of the Rockefeller Foundation, consists of eight private working rooms, a large physiological laboratory, and a similar chemical laboratory. There is also an up-to-date dark-room and photographic room. Beneath the building is a cellar hewn out of solid rock and fitted with a vibration-proof pillar. Here studies can be made under cool conditions. Abundant material for zoological, botanical, physiological, and biochemical research may be obtained from the waters of Plymouth Sound, and the laboratory staff makes every effort to secure special materials which workers require. The sea-water circulation in the aquaria runs through storage tanks, but outside sea-water is also provided. The whole laboratory occupies a very pleasant position on Citadel Hill, overlooking Plymouth Sound.

Foreign investigators have always been welcomed at the laboratory and are usually allowed to occupy tables without payment. Space is now available for about fifteen more workers than could previously be allotted places, and, together with other improvements, the Plymouth station offers considerably greater advantages along the newer lines of biological research than formerly.

J. P. SCOTT

[1] For a detailed description of the entire laboratory, see: Allen, E. J., and H. W. Harvey. 1928. The laboratory of the Marine Biological Association at Plymouth. *Jour. Marine Biol. Assoc.* U. K. 15: 735–828. The laboratory also publishes a fauna list of the Plymouth region, obtainable at Plymouth.

APPROPRIATIONS FOR FEDERAL GEOLOGICAL RESEARCH

ACCORDING to information sent by Science Service the elimination of fundamental geologic research in the U. S. Geological Survey and its investigation of mineral resources in Alaska is threatened in the appropriation bill for the Department of the Interior for the fiscal year ending June 30, 1934, reported in the House of Representatives on December 16.

The appropriations committee has eliminated completely the items for "fundamental research, geologic science" for which the budget estimated $46,470 and the item for "investigation of mineral resources in Alaska" for which the budget estimate was $60,180. In all the committee-recommended appropriations for the U. S. Geological Survey are $457,400 less than the budget estimates of $2,384,900.

Volcanologic surveys, largely in Hawaii, remain in the bill with $12,500, which is $2,500 less than the appropriations for 1933 and $6,010 less than the budget's recommendations.

If the appropriations for fundamental geologic research are not restored when the bill is considered by the House, the progress of geology in this country will be dealt a severe blow. The federal Geological Survey is the nation's principal research agency in geology, cooperating with universities and a few mining and oil companies which provide the only other organization supporting geological science.

The lack of appropriations for the Alaskan explorations would bring to an abrupt end the pioneer service under frontier conditions that was begun more than 30 years ago. Less than half of Alaska has been covered by the topographic and geologic maps necessary for any utilization of its resources.

Twelve investigators who have made geological service to the nation their life work would no longer be able to serve the public if the fundamental geologic research is killed by lack of appropriation. Cuts in geologic research have already been made, the budget recommendation of $46,600 being less than half of the $100,000 expended in the 1932 fiscal year. The elimination of Alaskan resources investigations would affect over twenty employees. The expenditures in 1932 for this work amounted to $84,500.

Other cuts included in the nearly half-million dollars eliminated from the reduced appropriations for topographic surveys by $62,000, geologic surveys by $35,700, stream gaging by $81,400, printing and engraving geologic maps by $64,170, investigations of minerals on public lands by $25,180, classification of lands by $72,950, general salaries by $3,340.

The whole Department of Interior bill recommends appropriations of $43,192,904 which is less than the budget estimates by $2,891,025. The only appropriations singled out for complete elimination in the whole bill are those for fundamental geological work and Alaska resources investigations of the U. S. Geological Survey.

So important are the geologic surveys, fundamental research and the Alaskan researches considered that under the economy act passed by Congress last spring additional funds for the current year were transferred by the Secretary of the Interior to these essential activities. Actual funds available for geologic surveys and fundamental research combined were $500,000 in 1932 fiscal year, $419,750 in 1933 fiscal year compared with the $300,000 proposed for geologic surveys and nothing for fundamental research proposed in the House committee report, a reduction of 40 per cent. in two years. For the Alaskan work $69,000 is currently available, compared with nothing recommended.

THE UNIVERSITY OF ILLINOIS AND THE TARIFF ON LABORATORY EQUIPMENT

THE *U. S. Daily* reports that the board of trustees of the University of Illinois on Dec. 6 filed a petition with the Supreme Court of the United States seeking a review of the ruling that the university is required to pay customs duties on laboratory equipment imported from abroad and used in educational work.

It is contended in the petition for a writ of certiorari that the imposition of customs duties on the equipment involved constitutes an unconstitutional burden and tax upon a state governmental agency. The university claims that it is a governmental agency of the State of Illinois, and that the equipment was imported in the exercise of a governmental as distinguished from a proprietary function. The Supreme Court is asked to hear the case and apply to it the rule that the Federal Government has no power to tax a state or any of the governmental agencies of a state.

Review is sought of the decision, with two judges dissenting, of the Court of Customs and Patent Appeals. The lower court stated in the majority opinion that it was necessary to determine in the case whether the university is a governmental agency. It was held that the rule sought to be invoked by the university is not applicable since the tariff law imposing the customs duties was an exercise by Congress of its power to regulate foreign commerce, and that Congress, having the sole power to regulate such commerce under the commerce clause of the Federal Constitution, has the power to subject merchandise imported by a state to customs duties.

The petition was filed by Attorney General Oscar E. Carlstrom, of Illinois, and Sveinbjorn Johnson, counsel for the Board of Trustees. Attorneys General of the States of California, Iowa, Kansas, Kentucky,

Minnesota, Mississippi, Montana, Nebraska, New York, North Dakota, Texas and Vermont also joined in the petition for review.

NATIONAL RESEARCH FELLOWSHIPS IN THE BIOLOGICAL SCIENCES

NATIONAL RESEARCH fellowships in the biological sciences (agriculture, forestry, botany, zoology, anthropology and psychology), are as usual to be awarded in 1933 by the National Research Council.

These fellowships are administered by a board appointed by the National Research Council. They are for study and research in America or abroad, and are open to citizens of both sexes of the United States and Canada who possess a Ph.D. degree or its equivalent. The purpose of these fellowships is the promotion of fundamental research through development of thoroughly trained investigators. The present policy of the board of administration is to restrict appointment to those applicants in the early stages of a research career who have demonstrated a high order of ability and who give promise of developing individual judgments and viewpoints in investigative work.

The basic stipends per annum are $1,620 for unmarried fellows and $2,070 for married fellows, in America; or $1,620 and $2,160, respectively, with additional travel allowance, for fellows appointed to study in Europe. Awards are made for one year, but fellowships may be renewed. Applications for 1933–34 must be in the hands of the fellowship board not later than March 1, 1933. Appointments will be made about May 1.

The fellowships are not granted to any institution or university, but the choice of place to work is left to the fellow, subject to the approval of the fellowship board. The appointments are for full time and no other remunerative or routine work is permitted.

For further information address: Chairman, Board of National Research Fellowships in the Biological Sciences, the National Research Council, Washington, D. C.

THE HERSEY PROFESSORSHIP OF THE THEORY AND PRACTICE OF PHYSIC AT HARVARD UNIVERSITY

A MEETING celebrating the 150th anniversary of the founding of the Hersey Professorship of the Theory and Practice of Physic, one of the first three professorships in medicine established at the university, was held on December 20, at the Harvard Medical School.

The professorship was established on December 24, 1782. In the 150 years since that time, it has had seven holders. The first incumbent was Benjamin Waterhouse, who held the post from 1782 to 1812. His successors have been James Jackson, 1812–1836; John Ware, 1836–1859; George C. Shattuck, 1859–1873; Francis Minot, 1873–1891; Reginald Heber Fitz, 1892–1908, and Henry A. Christian, who was appointed in 1908.

The speakers at the meeting were Dr. Christian, the present holder of the professorship, and descendants of his six predecessors. Five of these six descendants of the former professors are themselves now members of the teaching staff at the Medical School. The program, in addition to Dr. Christian's address, was as follows:

"Benjamin Waterhouse and the Introduction of Vaccination into America," by his great-great-granddaughter, Margaret Thayer Lancaster.

"James Jackson as Professor of Medicine," by his great-grandson, Dr. George R. Minot, professor of medicine.

"John Ware, the Family Physician," by his grandson, Dr. Robert M. Green, assistant professor of applied anatomy.

"George Cheyne Shattuck and his Medical Contributions," by his grandson, Dr. George Cheever Shattuck, assistant professor of tropical medicine.

"Francis Minot and Hemorrhage in the Newborn," by his grandson, Dr. Francis Minot Rackemann, instructor in medicine.

"Reginald Heber Fitz and Appendicitis," by his son, Dr. Reginald Fitz, associate professor of medicine.

SCIENTIFIC NOTES AND NEWS

IN view of the death of Dr. Louis W. Austin in July, 1932, Professor A. E. Kennelly has been elected to the presidency of the International Scientific Radio Union (Union Radio Scientifique Internationale) to succeed the late General Gustave A. Ferrié.

DEAN ANDREY A. POTTER, of the School of Engineering at Purdue University, was elected president of the American Society of Mechanical Engineers at the recent New York meeting.

THE Paul Ehrlich Foundation of Germany has awarded its gold medal to Dr. Oswald T. Avery, of the Hospital of The Rockefeller Institute for Medical Research, New York, and its silver medal to Dr. Michael Heidelberger, formerly of the Hospital of The Rockefeller Institute for Medical Research and now of the Medical Department of the Presbyterian Hospital and associate professor of biochemistry of the College of Physicians and Surgeons, Columbia University, for their "epoch-making chemo-immunological discoveries."

THE Carmalt lecture at Yale University has been postponed owing to the indisposition of Dr. William H. Welch, who was expected to speak on December 16 on "Nathan Smith and the Differentiation of Typhoid Fever."

THE trustees of Stanford University have extended until March 4, 1933, the leave of absence of President Ray Lyman Wilbur, Secretary of the Interior. Before becoming president of Stanford University Dr. Wilbur was professor of medicine and dean of the medical school.

COLONEL HERBERT ALEXANDER BRUCE, formerly professor of surgery at the University of Toronto, known for his work on cancer, has been appointed lieutenant governor of Ontario.

AT the recent meeting of the American Society of Tropical Medicine held in Birmingham, Alabama, on November 18, the following honorary members were elected: Sir Henry S. Wellcome and Dr. C. Morley Wenyon, Wellcome Bureau of Scientific Research, London; Professor Dr. Friedrich Fülleborn, Institut für Schiffs- und Tropenkrankheiten, Hamburg; Dr. Charles Wardell Stiles, Washington, D. C., and Winter Park, Florida; Dr. William S. Thayer (who has since died), the Johns Hopkins University, and Dr. Frederick G. Novy, University of Michigan.

SIR ARTHUR WILLIAM HILL, director of Kew Gardens, formerly scholar and fellow of King's College, has been elected to an honorary fellowship of the college.

PROFESSOR ADOLF BARTH, formerly director of the Clinic for Diseases of the Throat, Nose and Ear at Leipzig, celebrated his eightieth birthday on November 26.

SIR JAMES CRICHTON-BROWNE, London, known for his work on mental and nervous diseases, celebrated his ninety-second birthday on November 29.

M. W. STIRLING, chief of the Bureau of American Ethnology, has been elected a fellow of the Royal Geographical Society, London.

DR. ARTHUR F. BENTON, professor of chemistry at the University of Virginia, addressed on December 1 a meeting of the Virginia Chapter of Sigma Xi. His subject was "The Mechanism of Catalyzed Chemical Reactions." Dr. Benton and Dr. T. A. White won the president and visitors' research prize of the University of Virginia for 1932 for their investigations in this field of chemistry.

DR. NORRIS W. RAKESTRAW, professor of chemistry in Brown University, has been elected secretary of the Division of Chemical Education of the American Chemical Society in succession to Dr. Ross A. Baker, professor of chemistry in the College of the City of New York.

AT the regular meeting of the Rittenhouse Astronomical Society of Philadelphia, held on December 13 at The Franklin Institute, the following officers were elected for the year 1933: James Stokley, associate director, the Franklin Institute Museum, *president;* Professor Wm. H. Barton, director, the Hyatt Observatory, Pennsylvania Military College, *vice-president;* A. Clyde Schock, Philadelphia Central High School, *secretary;* S. W. Johnson, Swarthmore, Pennsylvania, *treasurer,* and Dr. J. T. Rorer, Wm. Penn High School, member-at-large of the Board of Governors. The society adopted a new constitution providing for active and associate members and for the admission of women.

THE following officers and new members of council of the London Mathematical Society have been elected for the session 1932–33: *President,* Professor A. C. Dixon; *Vice-presidents,* Professor S. Chapman, Professor H. Levy, Mr. T. L. Wren; *Treasurer,* Dr. A. E. Western; *Librarian,* Professor H. Hilton; *Secretaries,* Professor G. N. Watson, F. P. White; *New Members of the Council,* Professor J. C. Burkill, W. L. Ferrar, Professor E. A. Milne, Professor G. F. J. Temple, Professor E. C. Titchmarsh.

C. FORSTER COOPER, of Trinity Hall, has been appointed to the newly established readership in vertebrate zoology at the University of Cambridge, as from October 1, 1932.

DR. V. A. TIEDJENS, research specialist in horticulture at the New Jersey Experiment Station, has accepted a position as technical adviser to Yoder Brothers, greenhouse flower and vegetable growers at Barberton, Ohio. He will devote his time to the study of physiological problems with flowers and vegetables.

THE Calco Chemical Company, of Bound Brook, New Jersey, has established a grant of $750 to be devoted to research in water chemistry and has awarded it to W. E. Sansbury, graduate student in chemistry at the University of Florida. Mr. Sansbury will continue a study begun during the past year under the direction of A. P. Black, of that institution, on the use of ferric salts as coagulants.

COLONEL HUGH MILLER has resigned as professor of civil engineering at Union College, Schenectady. He will continue to teach during the present year, but will receive a year's leave beginning next June. He plans to make a study of engineering education in Europe under the auspices of the Institute of International Education during his leave.

DR. CORBIN T. EDDY, associate professor of metal-

lurgy at the Michigan College of Mining and Technology, Houghton, will sail on January 6 for Europe, where he will confer and study with leading students of dilatometry. He will work with Dr. Hans Esser at St. Etienne, France, and in the laboratory of M. Pierre Chevenard at the steel works in Imphy.

DR. S. C. BROOKS, professor of zoology at the University of California, Berkeley, is engaged in research in Tahiti, having been granted leave of absence until the middle of January.

DR. M. C. RAYNER, professor of botany at Bedford College, University of London, is visiting research institutions in the southwestern United States. During her visit she is a guest in the laboratory of Dr. H. S. Reed at the Citrus Station of the University of California at Riverside, where she is investigating the mycorrhizal associations of some types of plants in southern California.

PROFESSOR ANTON J. CARLSON, professor of physiology at the University of Chicago, gave the first Herbert Swift Carter memorial lecture on December 12 at the School of Medicine of Columbia University. Dr. Carter, who was known for his work on the digestive tract, was a professor in the school and a physician in the Presbyterian Hospital.

PROFESSOR DOUGLAS JOHNSON addressed the District of Columbia Chapter of the Society of Sigma Xi, November 29, on "Some Problems in Earth History." The preceding evening he led a discussion by members of the Pick and Hammer Club of the U. S. Geological Survey on "Problems of Marine Level Correlation."

DR. WM. CHARLES WHITE delivered the annual lecture of the Minnesota Trudeau Medical Society on December 6. The subject of his address was "Modern Progress in Tuberculosis Research."

DR. ALFRED C. LANE, head of the department of geology and mineralogy at Tufts College, addressed the Royal Canadian Institute at Toronto on December 10 on "The Authority of Science."

DR. PAUL R. HEYL, of the U. S. Bureau of Standards, delivered an address entitled "Romance or Science?" before the Philosophical Society of Washington on December 15.

DR. CHARLES G. KING, professor of chemistry at the University of Pittsburgh, lectured under the auspices of the Sigma Xi Club of the University of Buffalo on December 8. His subject was "The Antiscorbutic Vitamin."

MARKUS REINER, visiting research professor of Lafayette College, and engineer, Department of Public Works, British Government in Palestine, is giving a series of lectures on mathematical rheology at the John C. Green School of Engineering, Princeton University.

DR. JOSEPH L. DONNELLY, research associate in the physiological laboratory of the University of Cincinnati, has been given a grant by the Committee on Scientific Research of the American Medical Association to aid him in the prosecution of his studies on the physico-chemical changes incident to various coagulations.

AT its recent meeting in Richmond, the Research Committee of the Virginia Academy of Science made grants in aid of research to the following persons: Dr. Jesse W. Beams, physics, University of Virginia; Dr. J. C. Forbes, biochemistry, Medical College of Virginia; Dr. J. M. McGinnis, psychology, Hollins College; Dr. Carl C. Speidel, anatomy, University of Virginia; Dr. W. L. Threlkeld, chemistry, Virginia Polytechnic Institute; Major N. Beverley Tucker, chemistry, Virginia Military Institute; Dr. I. A. Updike, chemistry, Randolph-Macon College, and Mr. John B. Lewis for the Virginia Society of Ornithologists.

PREVIOUS awards from the Elizabeth Thompson Science Fund were reported in SCIENCE on March 15 and earlier. On May 27 the following awards were made: To Professor Everett P. Davis, University of Virginia, $207 to purchase a make and break type of light control together with the necessary mechanical features of operating a shutter in the light path; to Miss Madeleine P. Grant, Smith College, $200 for aid in completing studies dealing with the mechanism of secretion in the thyroid gland; to Mr. S. Sambursky, Institute of Physics, The Hebrew University, Jerusalem, $237 for aid in purchasing a Moll microphotometer to be used for measurement of the intensity of spectral lines in various light sources and under different conditions; to Professor S. W. Britton, University of Virginia, $100 for the purchase of chemicals and other supplies necessary in his study of the function of the adrenal glands. The trustees of the Elizabeth Thompson Science Fund meet ordinarily during the last ten days of the months of February, May and November. Applications for grants should be sent well in advance of the meeting to the secretary of the fund, Dr. Edwin B. Wilson, 55 Van Dyke St., Boston, Massachusetts.

IT is stated in *Nature* that the annual congress of the British Institute of Radiology was held in London from December 7 to 9, under the presidency of Professor F. L. Hopwood. The congress was officially opened by Sir George Newman. An exhibition of x-ray apparatus was organized by the British x-ray industry. The thirteenth Mackenzie Davidson memorial lecture was delivered by Dr. J. Chadwick on "The Neutron" and the fifteenth Sylvanus Thompson

memorial lecture by the Right Honorable Viscount Lee of Fareham on "Radium as a Therapeutic Agent —the Case for National Control."

PROTECTION for the great scenic Wawona Highway in Yosemite National Park was assured when President Hoover signed a proclamation on August 13 authorizing the addition of certain public and private lands to the park area. The proclamation covers approximately 8,785 acres, of which 5,061 acres are public domain and 3,724 acres are in private ownership, subject to all valid existing rights. Half of the purchase price of the private holdings along the road most important to its proper protection has been donated to the Government, and the Department of the Interior has been authorized by Congress to match this donation with federal funds. The Wawona Highway, which is now open to public use with the exception of the tunnel section through Turtleback Dome, runs from the south end of the Yosemite Valley to Mariposa Grove. Though it originates and ends within the park boundaries, the roadway runs for a considerable distance east of Mariposa Grove outside the park limits. The new boundary authorized by the President will bring this important highway entirely within the park boundaries, add a highly scenic area to the park, and greatly improve its boundary line from an administrative angle. It will increase the total area of the park to more than three quarters of a million acres. The Wawona tunnel, 4,230 feet long and regarded as a great engineering achievement, is 95 per cent. completed. Under the Emergency Relief Act of 1932 an allotment of $251,000 has been made to this project for permanent surfacing. This work will shortly be under way, and by next season a hard-surface road between Yosemite Valley and Mariposa Grove will be available to motorists. The approach road from Fresno to the new Mariposa Grove entrance is also being greatly improved with state and forest highway funds.

MEMBERS of the American Chemical Society have received from its secretary a letter dated November 21, asking their individual cooperation in maintaining the society at least at its present membership during 1933. Among the many letters received in reply is one from the president of the society, Dr. L. V. Redman, which is printed in *Industrial and Engineering Chemistry*. Dr. Redman writes in part: "I was very happy to receive your letter of November 21, urging the members of the society to see that the society did not suffer a contraction in 1933. I can hardly express to you the satisfaction which I have felt in the fine showing of the American Chemical Society in this year 1932—doubtless the worst year of the depression which we will have. We are at the bottom and beginning to turn the corner upward, but as you point out, it is just possible that we, as a society, may lag through 1933 unless there is every effort put forward by individual members to maintain the quality and number of members in the society. Without any doubt American Chemical Society journals are the best value of any commodity sold in the world. I know of no $15 which can bring such a record of results to a man's desk as does his membership in the American Chemical Society, and it would be absolutely unbelievable if it were not a fact. Any modern man who even dares to think that he is chemical in his outlook and hesitates about giving $15 for the journals is certainly not worthy to be called a chemist, or even a man who sympathizes with chemistry. If any man has even a mild interest in chemistry he ought to be willing to pay $15 to get so complete a record of the world's chemical work per year. At first I hesitated to say the world, and yet when you consider how complete our abstracts are, it is not an exaggeration."

DISCUSSION

THE ANCESTRY OF ECHINI

DURING the past three years a discussion has been going on which, while primarily of interest to students of Echinoderms, is really of great importance to all who are concerned with problems of phylogeny or the principles of evolution. For this reason, I beg for a little space in the columns of SCIENCE in which to call attention to the matter.

For many years students of Echinoderms and paleontologists in general have regarded the Ordovician fossil Bothriocidaris as the ancestor, or at least near the ancestral stock of the Echini. Recently, however, Mortensen, the eminent Danish zoologist and one of the foremost authorities on Echini, has decided to the contrary.[1] He has put forth the proposition that Bothriocidaris "can not be considered as an Echinoid at all" (p. 109), but "must be included in the class of the Cystoidea, not in that of the Echinoidea" (p. 111). He reached this conclusion after a critical study of seven specimens of Bothriocidaris, all the material available. It should be noted that Dr. Mortensen frankly advocates the hypothesis that primitive echinoids had pluriserial interambulacra, not the monoserial arrangement found in Bothriocidaris.

Naturally, so revolutionary a suggestion aroused

[1] *Vid. Med.*, 86: pp. 93–122, 1928.

the interest of all students of Echini, and there soon appeared a paper, "In Defense of Bothriocidaris," by Professor H. L. Hawkins, of Reading.[2] In his usual entertaining and convincing style Hawkins discusses Mortensen's paper in some detail and is satisfied that the Danish authority has quite failed to make a case. Some months later, Dr. R. T. Jackson, the author of the "Phylogeny of the Echini," one of the most accurate and carefully reasoned publications dealing with phylogenetic problems ever issued, entered the discussion of "The Status of Bothriocidaris."[3] This paper takes up with the greatest care and in the most courteous way each one of Mortensen's arguments and concludes with a clear summary of the 18 points on which Jackson bases his conviction that Bothriocidaris represents an ancestral stock for the Echini. His view is based on the close similarity of characters occurring in adult Bothriocidaris, as compared with those found as stages in development in the young of all later Echini.

Of course Mortensen could not ignore such opponents. He promptly renews the attack in a reply, "Bothriocidaris and the Ancestry of Echinoids,"[4] in which he presents new and valuable data derived from the study of seven additional specimens of the much discussed fossil. But the argument is virtually an elaborated reassertion of that in his first paper.

Next in the field is the eminent paleontologist of the British Museum, Dr. F. A. Bather, universally recognized as an authority on Echinoderms in general and as an exceedingly keen and skilful debater. Bather[5] discusses the question "What is Bothriocidaris?" admitting at the start that it is a question he has hesitated to answer. His final conclusion is that "Bothriocidaris was an echinoid which left no descendants," but he endorses Mortensen's position that Echini arose from an ancestral stock with irregular, polyserial interambulacra. The last contribution to the discussion is a second paper by Professor Hawkins, "The First Echinoid."[6] In this article Hawkins discusses the evidence for and against the monoserial and the polyserial condition of the interambulacra in the ancestral stock of Echini and concludes that the monoserial arrangement is the primitive one and that Bothriocidaris shows the nearest approach to that primitive stock of any echinoid known.

It has been suggested that since the opponents of Dr. Mortensen in this debate have hitherto all been paleontologists, it would be of interest, and perhaps of value in this discussion, to have the opinion of some other student of Recent Echini. As I may claim some familiarity with the group, I might then justify this communication on that ground. But there is a more important matter involved in the discussion than merely the ancestral stock of the Echini, and that is the principle of "stages in development" as fundamental in the discussion of phylogenetic problems. This principle, elaborated, if not originated, by Hyatt, and convincingly used by Jackson (his pupil), impresses me as of supreme importance. It is apparently recognized by Hawkins, particularly as applied to embryological development, but Bather (in this particular discussion) ignores it and Mortensen does not seem to have any appreciation of it. I can not pretend to such a grasp of the principle as Jackson has, but I hope I comprehend it sufficiently to use it correctly. It involves not merely the familiar idea that "ontogeny repeats phylogeny," but beyond that, throughout life, even in old age, each individual is repeating stages through which its ancestors passed. The clearness with which these stages are shown varies greatly in different groups, due to acceleration or retardation of development (or other factors). The Echini are a peculiarly satisfactory group in which to study stages, as the character of the test is such as to preserve and reveal them to an extraordinary degree.

In his "Phylogeny of the Echini," Jackson has been to the greatest pains to record and explain these stages, and has shown in that and in his other publications how supremely important they are for a correct understanding of phylogeny.[7] These arguments, which seem to me so weighty, Mortensen fails to appreciate, and hence he is impervious to Jackson's carefully reasoned presentation of the case for Bothriocidaris. Bather's statement that Bothriocidaris "left no descendants" seems to me based on a similar failure to give due weight to Jackson's argument. Hawkins at least gets the main point, but I must dissent emphatically from his suggestion that Echini may have been derived from holothurians. In my opinion, the holothurians are derived from some echinoid-like ancestor and are not a primitive group.

Mortensen's stress on the radial position of the madreporite as an argument against the echinoid nature of Bothriocidaris is overdone; the point does not seem to me weighty. His statement as to the absence of genital plates and pores merely shows that the genital openings in so primitive an echinoid were probably temporary and *between* the plates of the apical system; such temporary genital pores are found along the sides of the rays in many sea-stars. Finally, Mortensen's emphasis on the absence of a lantern is invalidated for me by one of his own figures (1930, p. 325, fig. 14); the fragments shown

[2] *Geol. Mag.*, 66: pp. 71–79, 1929.
[3] *Bull. M. C. Z.*, 69: pp. 481–512, 1929.
[4] *Vid. Med.*, 90: pp. 313–352, 1930.
[5] *Pal. Zeits.*, 13: pp. 55–60, 1931.
[6] *Biol. Rev.*, 6: pp. 443–458, 1931.

[7] For similar data in other groups see C. E. Beecher, 1901, "Studies in Evolution."

seem to me surprisingly like fragments of a lantern and teeth. The absence of a lantern in fossils of so primitive a type as Bothriocidaris would not seem to me surprising in view of the usual absence of any trace of a lantern in many (if not most) specimens of fossil Echini where yet one is known to have existed. These fragments figured by Mortensen are to me quite suggestive of the occurrence of a fairly typical lantern in Bothriocidaris.

I must give it then as my decided conviction that Mortensen's new data on Bothriocidaris strongly confirm the old view that that interesting fossil really represents an ancestral stock for all Echini, and amply justify Jackson's system of classification in the group.

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NUTRITIONAL REQUIREMENTS OF TROUT

DURING the past summer an agreement was executed between the U. S. Bureau of Fisheries, the New York State Conservation Department and the New York College of Agriculture at Cornell University for the purpose of conducting on a cooperative basis experimental studies in fish culture relating especially to fundamental problems of nutrition and physiology of fishes. Complementing, and to a certain degree paralleling, studies of fish feeding conducted at the bureau's experimental fish culture stations, the new undertaking will deal particularly with the digestibility of various nutrients by trout, the vitamin requirements essential to an economical and successful ration, and with enzymotic and other physiological and metabolism studies.

These investigations are under the direction of Dr. C. M. McCay, of the Animal Nutrition Laboratory at Cornell University, and are conducted in the bureau's hatchery near Cortland, New York, where the bureau will furnish suitable hatchery facilities, including the hatchery building and such rearing ponds as are needed, the stock of eggs and part of the feeds necessary for rearing fish. The New York State Conservation Department is providing the necessary funds for the compensation of the technical assistants involved in this work and for special apparatus and feeds needed for the experiments. The State College of Agriculture provides necessary laboratory facilities at Cornell University for experimental work and analyses not readily conducted on the hatchery premises. The bureau will incubate the eggs and will rear the surplus fish not needed for experimentation, which surplus at the end of the season will be available for filling applications for stocking adjacent waters. However, fish production will be subordinated to a vigorous prosecution of the scientific investigations in order to find ways of cheapening the operation costs in the several hundred hatcheries scattered throughout the nation.

Feeding experiments with brook trout were started at the Cortland experimental hatchery during the month of August and are being run by A. V. Tunison, who was formerly in charge of similar work in Connecticut. The feedstuffs that are being studied at the present time are dry buttermilk, cottonseed meal, peanut meal and a number of dry skim milks. These are the dry foods that have proved the most promising during the five preceding years during which similar research was carried out by Dr. McCay in Connecticut. In the present study the tests have been made more rigid than formerly by studying only feedstuffs of which origin and processing are known. This has been made possible through the cooperation of the producers' associations such as the American Dry Milk Institute. A series of dry skim milks, made by different methods, are involved in the testing.

Since one of the most important problems in using dry feeds is that of physical composition, a series of special binders are being tested. These binders are dextrins similar to those found in corn syrup. The method of preparation of each of these compounds from corn starch is known. Preliminary work indicates that one of these dextrins is quite superior to the others, but it is too early to anticipate which one of the dry skim milks will prove the most satisfactory. The spray process milk is better when only physical composition is considered.

All earlier work has shown that trout will grow well upon dry skim milk alone for twelve to fourteen weeks. After such a preliminary growth period they die quite rapidly unless this diet is supplemented with raw meat. In order to develop a concentrate of this raw meat factor some method of assay must be established. For this work the policy of feeding dry skim milk for three months has been adopted. After this period, when the body reserves are exhausted, special preparations will be fed as supplements to determine if they are as potent as raw meat in permitting the trout to continue growth and life. This method of testing is similar in principle to that now employed in measuring the vitamin A potency of cod liver oil.

In addition to studies upon brook trout two experiments are being run with groups of brown and rainbow trout in order to secure growth curves under identical water and feeding conditions. All earlier studies have shown that trout upon full feed increase their body weights during the growing season by a constant percentage. This is true of none of the higher animals, since they all grow very rapidly when young and gradually cease to grow as they approach adult size. Only two growing seasons have been

studied previously with trout. New groups are being established to be continued for a series of years, since the rate of growth is one of the factors in the economy of producing fish for food.

During the past summer, experiments were started in the Animal Nutrition Laboratory at Cornell University upon fish to learn more of their digestive processes. This involved the use of aerated aquaria with fish taking oxygen from the same water for periods of several days. An aquarium was discovered which operates very satisfactorily when aerated by the ordinary inexpensive suction pump that can be attached to any water faucet. The aquarium in this case was an earthenware jar with a lid of special design and ground to fit.

HENRY O'MALLEY
U. S. Commissioner of Fisheries

PARTHENOCARPY AND SEEDLESSNESS IN VITIS VINIFERA

SEEDLESSNESS in *Vitis vinifera* has been reported on by Muller-Thurgau in 1898 and 1908 and by Y. Oinoue in 1926, but no thorough microscopical investigation of this subject has hitherto been undertaken. This report deals only with the two most important commercial varieties of seedless grapes, Sultanina, or Thompson's Seedless, and Black Corinth. Muller Thurgau states that Sultanina ovules are incapable of being fertilized, although the pollen tubes enter the ovules, and that the Black Corinth ovules are also incapable of being fertilized, but that their pollen tubes do not enter their ovules. Oinoue reports that in both of these varieties one male nucleus fertilizes the egg, but that the secondary nucleus of the embryo sac is never fertilized and gradually disintegrates. The author finds, however, that a high percentage of Sultanina embryo sacs are perfectly normal at anthesis and are fertilized normally. At the time of anthesis the polar nuclei have already fused and the antipodals completely disappeared. According to A. N. Berlese, and the author's own investigations, this is the normal condition in seeded varieties of *Vitis vinifera*. Even in seeded varieties, a high percentage of abnormal embryo sacs occurs.

Within two or three days the pollen tubes can be seen traversing the nucellar cap and entering the egg apparatus.

Almost immediately after the entrance of the pollen tube the secondary nucleus, instead of degenerating, as reported by Oinoue, divides and redivides. When pollen tubes could not be found in several cases examined in which the stigma had apparently been injured, the secondary nucleus remained undivided.

Development beyond this stage varies greatly. In normal grape seeds the endosperm does not encroach much upon the nucellus until the seed has reached approximately its full size, and the embryo hardly begins its development for perhaps several weeks after fertilization. Sultanina seeds frequently develop some endosperm tissue, and embryos of over a hundred cells have sometimes been observed.

However, the abnormal conditions which are correlated with the final degeneration in Sultanina seeds can always or nearly always be readily detected even at the time of anthesis. In the region of the micropyle, among other abnormalities, the inner integument is much exserted beyond the outer and often curved back up the side of the ovule. In a normal *Vitis vinifera* ovule the outer integument at least equals the inner. Within two weeks after fertilization the entire seed coat development has very obviously gone astray.

It is not claimed that the abnormal physiological conditions in the Sultanina ovule never prevent the formation of a perfect embryo sac, but the author believes that as a rule, at least one normal embryo sac has been developed and fertilized in each normal Sultanina berry.

In the Black Corinth, on the other hand, there are, as a rule, no normal embryo sacs. Occasionally a seeded berry sets, and in the course of an examination of thirty or forty berries two or three embryo sacs appeared to be normal. But ordinarily all four embryo sacs are in various stages of disintegration at the time of anthesis. The polar nuclei have almost never fused. The egg apparatus may be missing entirely or in various stages of degeneration. Often the only nuclei in the sac are three or four clumped together in the center of the sac. The pollen tubes enter the locules in the great profusion characteristic of seeded varieties of grapes, but they seldom enter the micropyle and only rarely penetrate the nucellar cap.

Further details will be published later.

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PHOTOPERIODISM AND CHRYSANTHEMUM PRODUCTION

THE production of flowers early in the season when prices are usually highest is one of the problems of the present-day florist. This end is quite often obtained by early planting, heavy feeding and correct pinching of buds.

With chrysanthemums in Colorado these practices do not produce flowers early enough to be of material value economically. Chrysanthemums yield readily to shortening of the daylight period and earlier flowering results from shading. While this fact has been

known for a number of years, to the writer's knowledge it has not been made use of commercially. The past two years this practice has been carried out on an extensive scale in Denver greenhouses.

A greenhouse of 8,000 square feet of glass was equipped with black cloth shades that covered the entire crop of chrysanthemums in this house. These shades, or curtains, slid on rings on wires inside the house and could be quickly drawn off and on. The shading was begun on July 10 and continued until the terminal buds were well formed. The shade was placed over the plants about 4 P. M. and left there until about 8:30 A. M. the following morning. This practice brought chrysanthemums into bloom and on the market from 14 to 50 days earlier than the same varieties planted at the same time but not shaded.

Another house of 10,000 square feet of glass was arranged and similarly planted to the pompon type of chrysanthemum. These plants produced flowers from 16 to 30 days earlier than the same varieties without shade.

The quality of flower, length of stem and keeping quality is apparently unaffected by this practice of shading, especially in the midseason or late varieties. The earlier varieties, when shaded, however, tend to have smaller flowers and shorter stems.

The advance of the cutting period is of great economic importance, since it places flowers on the market when few or no flowers of that kind are to be had, with resultant favorable prices.

E. J. STARKEY

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SCIENTIFIC BOOKS

Bibliography of the Honourable Robert Boyle, Fellow of the Royal Society. By J. F. FULTON, M.A. Oxon. (Oxford Bibliographical Society, Proc. and Papers, Vol. 3, Pt. 1, 1931). Oxford, Oxford University Press, 1932.

THE handsome and scholarly publication before us for review calls vividly to mind the fact that the art and the science of bibliography have not as yet passed entirely from the minds of scholars. Nor has the appreciation of first-rate work waned because of the fact that so little bibliographical work is done. Of course there are "types" of bibliographical production ranging from a mere author-title compilation to extended and annotated lists and even abstracts. These, however, are good enough for ordinary scholarly and commercial use, but when it comes to preparing a bibliography such as has Dr. John F. Fulton, of the School of Medicine of Yale University, we are then dealing with the highest type of scholarly bibliography —compiled primarily for the critical scholar and librarian. Dr. Fulton has shown many fine traits in the preparation of his study of Honorable Robert Boyle's work. He not only has examined each of 258 items, but he has virtually weighed each one. There is a total of 367 entries in the bibliography. The results of his study are clearly shown by the exactness of the bibliographical data assembled. In his introduction, Dr. Fulton says:

> In order to disclose these things a modern bibliographer must "anatomize" his books: he dissects them with infinite patience, lifting their epidermis to find what lies beneath; he is concerned with their joints and ligaments, and has great delight in discovering parts which have been artificially replaced; he seeks for errors in the hand of the maker, but he views with charitable amusement all signs of human frailty. Bibliography is indeed an all-absorbing occupation, but its devotee is frequently face to face with those who fail to understand the source of his enjoyment. A mere list of bibliographical idiosyncrasies with mistaken signatures, pagination, and gatherings, has little appeal to any one not a collector of books; and however much a bibliographer may pride himself on "purity" he has difficulty in justifying his existence if he fails to make himself useful to those not pursuing his specialized field. He must reveal something more than the mechanics of bookmaking. He can endeavor to assess the importance of a book; he may say how the author came to write it, or investigate the influence which it exerted upon his contemporaries. With Boyle one can sometimes deal with these and related questions, and I have attempted to do so in the preliminary notes concerning each of his separate works. With his more obscure writings, however, the task has been difficult, and many of my notes will be found incomplete and inadequate.

The question as to the necessity of this sort of work is answered in the publication itself. The apparently growing interest in the life and work of Robert Boyle has called for further examination, particularly from the point of view of the historian of science. His work was the link between the alchemy of the Mediaeval Age and the chemistry of the modern period, which every reader of the "Sceptical Chymist" will discover for himself. He was one of the illustrious founders of the Royal Society of London, together with Wren, Hooke, Ashmole, Barrow, Wilkins and others, who represent the pioneer age of scientific progress in Great Britain.

The complete bibliography of the writings of Boyle reveals subjects of varied character, showing him to be almost encyclopedic in learning. Dr. Fulton has

had unusual opportunities to examine Boyle's work, and this bibliography is the result of his remarkable researches.

The preface of this bibliography states clearly how the work came to be compiled, together with the source or location of many of Boyle's works. This is followed by a table of contents, consisting of four divisions: (a) separate works of Boyle, which is divided into 42 sections, wherein is described each book, together with a historical account as to how the work became known; (b) contributions to other works, including papers in the Philosophical Transactions of the Royal Society; (c) collections with Opera Varia; (d) biography and criticism, together with Appendices and a General Index. There are twenty-two facsimiles of title-pages and other illustrations of importance, with a portrait bust of the Honorable Robert Boyle, by J. M. Rysbrack, as a frontispiece. At this point it may be suggested that Dr. Fulton should have included a list of all the famous portraits of Boyle, together with the artist's name, location of these paintings, etc.

It is very apparent that the compiler has taken into account every known copy of the various editions of Boyle's writings. He has revealed how rich the various college libraries of Oxford and Cambridge universities are, as well as the British Museum and several continental libraries, and a number of private collections. It is to be regretted that the initials "L. C." (Library of Congress) are not among these references. A most astonishing thing is the large number of titles contained in Fulton's own private library.

This is not the sort of bibliography to be criticized by merely a study of its pages and contents—one can not presume even to evaluate the various items, unless he himself has access to the collections. In other words, Dr. Fulton has left no room for attack upon any phase of the complete bibliography. The care which he has given each and every item is very evident. He has described in full each book, using the various bibliographical and typographical symbols. To the last, the reviewer had hoped to find a place for attack, but a check upon the index showed that it had been compiled with care and caution.

The bibliography is unusual also, from the point of view that it is readable, fascinating and entertaining. As well as being of great use to the scholar in literature and science, its references and information are a great help to the librarian, and its beauty in form, type and printing will be appreciated by the typographical student.

FREDERICK E. BRASCH

LIBRARY OF CONGRESS

Johann Kepler, 1571–1630. Special Publication No. 2 of the History of Science Society. xii + 133 pp.; two plates. The Williams and Wilkins Company, Baltimore, 1931.

THIS little book contains three addresses delivered in commemoration of the tercentenary of Kepler's death at a joint meeting of the History of Science Society and Sections A, D, and L of the American Association for the Advancement of Science at Cleveland in December, 1930; and a bibliography by the secretary of the editorial committee in charge of publication.

The first part, "Kepler as an Astronomer," by W. Carl Rufus, is a lively and interesting presentation of the most important biographical facts about Kepler and of his astronomical achievements. Professor Rufus' concluding remarks seem to imply that modern physicists are tending to return to the outlook on the universe which dominated him, and even that this is a good thing. It seems to the reviewer that only a very thorough-going and detailed analysis of the matter could justify either the implication or its evaluation. Such an analysis has not been given and is obviously beyond the scope of this part of the book.

Part 2, "Kepler as a Mathematician," is by D. J. Struik. This is an orderly, authoritative and liberally annotated account of Kepler's contributions to mathematics. These included important adumbrations of the methods of the differential and integral calculus, investigations in the theory of regular polygons, and tables of "Keplerian" logarithms. Like the Naperian logarithms, these last were quickly superseded by those of Briggs, but nevertheless remained long in view by virtue of being used in the Rudolphine Tables. In general Kepler's mathematics seems to have lacked rigor, but not usefulness.

Part 3, "Kepler and Mysticism," is by E. H. Johnson. It is one of the commonplaces of history that the esteem in which a pioneer holds his scientific discoveries may differ profoundly from that of his successors. No better exemplification of this can be found than Kepler. In his work the famous three laws appear to us at first sight like gems, surrounded by masses of irrelevancies and mistakes. To Kepler, they were integral parts of a unified scheme, no more necessary to it, and not more to be celebrated than the other parts. It is evident from this that Kepler's mind was dominated by a set of ideas (both expressed and tacitly assumed) which was in many ways far different from that which conditions the modern outlook on the universe. Kepler was thus driven to seek and find emotional satisfaction in constructing vast systems that now seem chimerical in comparison to our own, but which fortunately contain some elements

still useful and even essential to ours. There seems to be need of a biography that would shed light on the specific ways by which these ideas entered Kepler's mind, on the way in which they were modified by the circumstances of his life and how they bore fruit in his works. While the third part of the book makes it clear that there is an interesting and important study to be made here, it does not seem to contribute much of a specific or exact nature to it.

Part 4, by Frederick E. Brasch, is an accessible and extensive bibliography of works by and on Kepler. It has the great advantage of brief descriptive notes on many of the important entries.

R. I. WOLFF

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Antony van Leeuwenhoek and his "Little Animals." Being some account of the father of protozoology and bacteriology and his multifarious discoveries in these disciplines. Collected, translated and edited from his printed works, unpublished manuscripts and contemporary records. By CLIFFORD DOBELL, F.R.S., protistologist to the Medical Research Council, London. Harcourt, Brace and Company, New York, 1932. Price, $7.50.

THIS book was published on October 24, 1932, on the 300th anniversary of Leeuwenhoek's birth. It covers 435 quarto pages and contains 32 full-page plates, consisting of portraits of Leeuwenhoek, facsimilies of his hand-written letters to the Royal Society in London, figures of bacteria, spirochaetes and protozoa reproduced from original drawings in his manuscripts, illustrations of Leeuwenhoek's "Microscope" and his pepper tube, and scenes of Delft which were intimately associated with Leeuwenhoek's everyday life. The book contains over 600 references to works referred to in the text and gives a short list of Leeuwenhoek's writings. The author gives Leeuwenhoek the title "Father of Protozoology and Bacteriology."

Dobell, with the background of a busy lifetime of research as one of the world's foremost protozoologists, interprets for the reader in copious footnotes Leeuwenhoek's simple descriptions of his "little animals" and identifies them in terms of present-day zoological and bacteriological nomenclature.

The value of the book to the reader is unspeakably enhanced by the circumstance that its author laboriously mastered the Dutch language of Leeuwenhoek's time that he might truly breathe the spirit of Leeuwenhoek's words into his English translation of the original manuscripts still preserved by the Royal Society in London.

The standards of Leeuwenhoek's micrometry of the "animalcules" are discussed—a sand-grain, a human red blood corpuscle, a vinegar-eel, the diameter of a louse's eye, the bigness of a hair on a louse, the thickness of a spider's web and the bigness of a cheesemite.

The modern research worker, housed by towering walls, equipped with elaborate apparatus all ordered from catalogues, and assisted by a multitude of specialists: Contrast him with the Dutch janitor and his simple tools—a home-made lens, some rainwater, some pepper water, some vinegar, some thin pipes of glass and some spittle.

Leeuwenhoek's secret, which he never revealed in any of his writings or to anybody and which was buried with him, concerned the method by which he observed objects with his microscopes. Microscopes he gave and left aplenty, but Leeuwenhoek alone could see with them the minutiae of bacteria and protozoa which he described. One is stunned at the discoveries which he made with his limited equipment. Dobell supplies a notion in elucidation of the missing method by which Leeuwenhoek observed flagella, cilia and spirochaetes.

The dedicatory page affectionately names Paul de Kruif, who in "Microbe Hunters" rates this shopkeeper of Delft "First of the microbe hunters."

The printing and binding of this magnificent book are perfect specimens of the printer's art.

EDWARD FRANCIS

SCIENTIFIC APPARATUS AND LABORATORY METHODS

IMPROVEMENTS IN BIOLOGICAL LABORATORY APPARATUS

THE electrical thermostat without water-jacket has come permanently into use in biological laboratories. Its extreme convenience has made that inevitable. It has one serious disadvantage, however, namely, that the heater is apt to cause explosions if by any means a mixture of air and vapor or air and gas is set free inside the system. Some quite serious accidents have occurred in biological laboratories throughout the country on this account. The rapidly increasing use of hot nitro-cellulose, where the most perfect results in embedding are to be obtained, has made the danger of explosion much more in evidence.

The heater in baths of this type is either directly exposed inside the bath or, if shut off from the main cavity, is surrounded by walls which naturally have apertures to allow the heat to make its way. In either case the conditions for an explosion are present, since the heated wires which produce the necessary tempera-

ture are red hot or even incandescent. At the writer's suggestion the makers of some of these baths have adopted the device more than a century old, which we owe to Sir Humphry Davy, namely, the enclosing of the incandescent heater with a wire gauze envelope. This is an advantageous arrangement in baths in which the heating unit is shut off from the main cavity by walls. In baths where the heater is exposed on the floor it is sufficient merely to lay a double thickness of moderately fine mesh wire gauze over the top of the heater. The writer has experimented with baths so safeguarded by pouring ether directly on the heater, and under these circumstances there was neither explosion nor flame produced.

Another desideratum in biological laboratories for microscopic use is a powerful light of the incandescent bulb type, which will be reasonably durable. The ribbon filament bulb has been extremely satisfactory so far as supplying powerful light is concerned for use with high power objectives and particularly with binocular microscopes, in which necessarily there is considerable loss of light. The great objection to the ribbon filament bulb has been its short and extremely uncertain life. The brevity of its usefulness is due apparently to two causes, namely, the fact that the contact at the base of the bulb is made of readily fusible solder which melts on account of the heavy current used and in that way brings about disturbances which shorten the life of the bulb. This difficulty has been obviated. Another difficulty is presented by the ribbon filament itself. This in the present type of lamp is two millimeters wide and rather thin. On account of its insufficient thickness it breaks down prematurely at the points where it is inserted into the leads. It is proposed to overcome this difficulty by using a filament 50 per cent. thicker and only a millimeter and a half wide. It is hoped that with these improvements the ribbon filament bulb, which is an extremely satisfactory source of light aside from its uncertainty of life, will become more reliable in the latter respect. These improvements have been brought about at the writer's suggestion through the cooperation of the General Electric Company, Incandescent Lamp Department, and the Bausch and Lomb Optical Company.

E. C. JEFFREY

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ON VOLUMETERS FOR SOLID BODIES

A MUCH more satisfactory volumeter than those generally mentioned in literature is one which rests on the principle of a siphon, of which the extremity outside the liquid is below that in the liquid. An inverted funnel, of mouth diameter 2.5 to 3 cms, or more (B in Fig. 1) is connected to a rubber tube (c), which in turn is connected to a glass tap (D) outside the apparatus; the wide mouth (b) of the funnel serves to break the column sharply and without gurgling. By means of the glass tap, water is sucked up to fill the siphon completely to the tap (using the tongue as valve) and then it is closed and placed in a fixed position in a stand. When the water is at rest the tap is opened to the mark (d), and after the water stops running the body is inserted in the volumeter, water again sucked up as noted above, etc., carefully replacing the tap in the same position and opening the tap to the same mark.

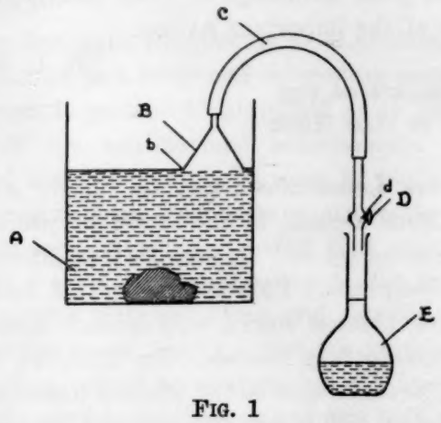

FIG. 1

By this means a volume of a liter or more, for which the apparatus is particularly recommended, may be measured to 0.1 per cent. in about 20 seconds, when the apparatus is ready for use.

Larger (or smaller) funnels may be used in the apparatus, but then greater care must be exercised to open the tap to exactly the same mark each time, for if the speed of flow of water is different after the body is inserted to before, a greater error in the volume of the body in question will result than with a funnel of the above dimensions.

In the case of larger funnels, if the speed of flow of water after the body is inserted is smaller than before it is inserted, the volume found will tend to be smaller than that of the body, and *vice versa, e.g.,* with a funnel of 14.5 cms diameter a change of speed from about 4,000 cc per minute before insertion of the body, to about 100 cc per minute after insertion gave a volume about 45 cc too low.

In the case of smaller funnels, on the other hand, (*e.g.,* one with a niche) the volume found will tend to be larger if the speed of flow is smaller after the body is inserted, and *vice versa, e.g.,* a change in the speed of flow from 1,500 cc per minute before, to about 100 cc per minute after insertion of the body gave a volume nearly 60 cc too high.

With a funnel of mouth diameter 2.7 cms a change of speed from about 1,500 cc per minute to about 100 cc per minute gave a volume not even 4 cc too high.

This remarkable reversal in the dependence on the

size of the funnel mouth, of the relation between the volume siphoned over, cet. par., and the speed of flow of water, is explained by two combined and contrary effects—(a) without interference of water current at the edge of the funnel mouth (as *e.g.*, in the case of wide funnels) more water is siphoned over in the time taken for the water surface to break away from the glass when the maximum tension is exceeded, if the speed of flow of water is greater; (b) the stronger the water current at the edge of the funnel mouth the more prematurely does the water surface break away from the glass.

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AN IMPROVED METHOD FOR THE STUDY OF DIFFUSIBLE BACTERIAL PRODUCTS IN VIVO

CELLOIDIN capsules containing cultures of living bacteria have frequently been used by bacteriologists and pathologists in studying the action of diffusible bacterial products *in vivo*. The usual method has been to place such capsules in the abdominal cavity of laboratory animals and note subsequent pathological changes. Such a method, in which the bacteria are confined by a semipermeable membrane, has the advantage of simulating a focal infection, but, because of the fragility of the container, it has not proved to be as useful as the experimental method warrants. Home-made capsules of this type are difficult to make, and even when successfully produced they are peculiarly liable to rupture as the result of manipulation or the activity of the animal, and the results are obscured or invalidated by the sepsis which ensues.

While studying the effects of certain bacterial toxins on the leukopoietic system of the rabbit, the writer has used the above method with success, but instead of using a celloidin container, a capsule was prepared by taking two parchment dialyzing thimbles (about 1½ centimeters in diameter) of the type commonly used for purifying bacterial toxins, cutting them down to a length of 2½ centimeters, and fitting one over the other to make a capsule of the same type as the gelatin capsules used in administering powdered drugs by mouth. The two parts were rinsed out with alcohol just before fitting them together, and the capsule was then sealed with celloidin, which was hardened with water. Such capsules were filled with 5 cc of broth cultures of bacteria by means of a sterile fine gauge needle and syringe, and the needle hole sealed with celloidin. Each capsule was rinsed off in alcohol immediately before being placed, with aseptic precautions, in the abdominal cavity of a rabbit.

Only two of fifteen rabbits used in our first series were lost from sepsis, and in each case the leakage was due to the capsule being used before the celloidin cement had hardened sufficiently. If properly prepared these capsules are remarkably substantial and will withstand any amount of manipulation involved in the operation. A pure culture of virulent *Streptococcus hemolyticus* was found on opening a capsule twenty-eight days after operation, and other animals are continuing to show evidence of the viability of the cultures which they contain, after an elapse of more than two months. This method is particularly valuable in the study of diffusible bacterial products which are slow in their action, but which are capable of causing pathological changes in the host.

In our experiments we have been using Abderhalden dialyzing thimbles, but similar products which should be quite satisfactory are listed in the catalogs of a number of the American laboratory supply houses.

E. W. DENNIS
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THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE ATLANTIC CITY MEETING

THE general program of the ninety-first meeting of the association has already gone to press and will be available on Tuesday morning, December 27, at the registration offices in the Municipal Auditorium, Atlantic City. This program will be a book of 225 pages and will contain the titles of over 1,300 papers on practically all topics of scientific interest.

The program of general sessions includes lectures on a wide range of subjects—mathematics, physics, chemistry, zoology, botany, sociology, engineering and medicine. The lecturers will be Dr. Franz Boas, Dr. H. N. Russell, Dr. Harlow Shapley, Dean Dexter S. Kimball, Dr. R. C. Tolman, Dr. R. W. Wood, Dr. Russell W. Bunting, Dr. Dayton C. Miller, Dr. C. C. Speidel, Dr. Mel T. Cook, and Dr. O. H. Caldwell. For titles of these lectures see SCIENCE for November 18.

General sessions of the association will be held in the Municipal Auditorium and in Haddon Hall, which will be headquarters for the association. Sessions of the sections and of the forty-one societies, in general,

will be held in the hotels used as headquarters, but a few societies—the American Physical Society, the American Society of Zoologists, the American Society of Parasitologists and the Genetics Society of America—will hold their sessions in the Municipal Auditorium, which is centrally located on the Boardwalk. For a list of societies meeting with the association see SCIENCE for October 28.

Dr. Franz Boas, the retiring president of the association, will deliver his presidential address at the official opening session of the association on Tuesday, December 27, 1932, at 8:30 P. M. in the Ballroom of the Municipal Auditorium. He has announced his subject as "The Aims of Anthropological Research." Following Dr. Boas' address a general reception for members of the association and friends will be held in the Vernon Room (not in the Rutland Room, as previously announced) of Haddon Hall.

A number of societies and sections have organized important symposia (see SCIENCE for November 11). Dr. R. A. Millikan and Dr. Arthur H. Compton, Nobel prize winners in physics, will participate in a symposium on "Cosmic Rays," which will be held on Wednesday morning, December 28, at 10 o'clock, in the Municipal Auditorium. Distinguished economists and engineers will participate in a symposium on "The Stabilization of Employment" that will be presented on Wednesday at joint sessions of Sections K and M.

The tenth award of the American Association's prize of $1,000 for a noteworthy paper will be announced on Saturday, December 31, at the close of the meeting. Rules regarding the prize will be published in the general program.

A general election of officers will take place at sessions of the council in Atlantic City. Association officers to be elected include the president, the general secretary, the permanent secretary, the treasurer, fifteen vice-presidents and fifteen secretaries of sections. The first council meeting will be held on Tuesday, December 27, at 3:00 P. M. in Room 133–137 of Haddon Hall. Other sessions of the council will occur on Wednesday, Thursday and Friday morning at 9:00 o'clock in the same room. Business to be presented to the council must first be considered by the executive committee. Matters to be considered by the executive committee should be transmitted through the permanent secretary who may be reached in Haddon Hall.

CHARLES F. ROOS,
Permanent Secretary

THE PRESS SERVICE

COOPERATION is the spice of human existence, without which life is flavorless and insipid and scarcely seems worth while. More and more cordial in recent years have become the relations between the Press Service and the members of the association, until at the present time it is difficult to see how they could be improved.

Modern publicity with many of us is a difficult pill to swallow. The reason is that science deals wholly with the unemotional exposition of facts, whereas the newspaper reading public demands "human interest"—that is, emotion in some form—in everything put before them.

The press representatives, always conscientious and most anxious to present science accurately, must necessarily write in terms that will interest the average man. Let us see how this has come about. It is well illustrated by the press history of our own meetings.

In 1873 the *New York Tribune* published, as "Extra No. 10" in its "Scientific Series," forty-two columns on the twenty-second meeting of the association held at Portland, Maine. This account was illustrated by wood-cuts of the brain of a female fox, oceanographic apparatus of various kinds, and deep-sea animals that had recently been dredged up by the newly established U. S. Fish Commission.

The scientific names of animals were freely used, and there was a long list of names of invertebrates brought up in a single dredge haul six miles east of Seguin Island. But together with this detailed account of the proceedings of the association we find an advertisement of a phrenological journal that "teaches choice of pursuits, self-culture, &c." Also we see an advertisement inserted by an ex-army officer, a graduate of West Point, who wishes an engagement as professor of mathematics.

In those days education and the reading of newspapers were limited to a small portion of the population, who regarded education as more or less synonymous with culture, and who were willing to read and try to understand anything that appeared to have the possibility of increasing their knowledge, and therefore their culture.

With the spread of education among all classes of the population the great majority of the newspaper readers came to be found among the more emotional elements; so, of necessity, reports of scientific meetings were clothed in more or less—usually more—emotional language.

During the past decade there has been a determined effort on the part of the press to make science not only interesting to the average newspaper reader, but also accurate. And the members of the association have cordially done their part by making their contributions, so far as possible, intelligible to the average man.

It is a real pleasure to be able to say that never before has the material submitted to the Press Service

in advance of a meeting been so abundant and so wholly satisfactory as that sent in in connection with the Atlantic City meeting. The cordial cooperation now obtaining between the members of the association and the Press Service is indeed most gratifying.

AUSTIN H. CLARK,
Director of the Press Service

THE SCIENCE EXHIBITION

THE Science Exhibition at Atlantic City will be held in the Grand Ballroom of the Municipal Auditorium from Tuesday noon, December 27, until Friday evening at 8:00 P. M., December 30. The exhibits are divided into three categories, those pertaining to science and research, those from commercial concerns and special demonstrations of hobbies of science.

The exhibits on cosmic rays will perhaps be more complete in representing recent work than in any other field. Professor A. H. Compton will show some of the apparatus used in his recent research work in measuring these rays in widely distributed parts of the earth. There will be shown the steel ionization chamber about four inches in diameter filled with argon at thirty atmospheres pressure. An electrometer measures the intensity of the cosmic rays.

The Bartol Research Foundation of the Franklin Institute will have two demonstrations with cosmic rays; one which measures and records coincident passages of the cosmic rays through two chambers which are in line. This will enable the visitors to see the records of the cosmic rays coming from a given direction at Atlantic City. The other demonstration is a cosmic ray hodoscope or track-viewer. In this demonstration the visitors will be enabled to see the path as made by the cosmic rays.

Dr. Robert A. Millikan, it is expected, will find it possible to have in the booth from the California Institute of Technology some of the equipment that he has used in his cosmic ray investigations.

The Rice Institute will have the Geiger-Counter Cosmic-Ray Apparatus, developed by Dr. L. M. Mott-Smith. This is a demonstration of a triple coincidence Geiger-Counter for the study of cosmic radiation. It will be shown in this demonstration that the cosmic radiation comes in most strongly in the vertical direction, and that the particles which produce the coincidence travel along nearly rectilinear paths. This equipment also gives a measure of the intensity of this radiation. Dr. Mott-Smith and L. G. Howell, jointly with Captain A. W. Stevens, of the U. S. Air Corps, will have a recording cosmic ray electroscope. This is a high pressure electroscope and photographic mechanism used in airplanes for recording cosmic ray intensity at high altitudes.

Another exhibit that every member of the association will be interested in seeing is that of Professor Walter R. Miles, of the Institute of Human Relations at Yale University. Professor Miles is demonstrating the Flickerometer and the Kinephantoscope, but the outstanding feature of this exhibition is an actual, working psychological laboratory in which the members of the association and others may have psychological measurements made upon themselves with particular reference to mental alertness and personality tests. This exhibition should be as interesting as that of Dr. A. F. Blakeslee at New Orleans.

There are nineteen commercial exhibitors, in spite of economic conditions that with many industries have completely stopped the exhibition business. We greet for the first time this year some exhibitors who have used science in their business. As an example, the Ford Motor Company will show work in connection with the Johannsen gages as a part of the product of their gage factory.

In the Science Library will be seen practically all the science books published in America in 1932. The number is approximately 324.

Each day at the tea hour there will be demonstrations in connection with the hobbies of scientific men. On Tuesday at 5:00, Dr. W. F. G. Swann, president of the American Physical Society, will appear with his 'cello. He will tell some things in connection with this hobby and will give demonstrations. On Wednesday, Dr. Dayton C. Miller, professor of physics at the Case School of Applied Science, will appear with about forty flutes and will tell something of the manner in which he mounted and rode his hobby. He will also give some demonstrations on these instruments. The same afternoon Professor David Eugene Smith, of Columbia University, will tell about one of his hobbies, namely, Oriental books. Professor Smith has ridden more than one hobby successfully. The mathematicians all know of his collection of historical instruments pertaining to mathematics and astronomy. On Thursday Dr. C. N. Hickman, of the Bell Telephone Laboratories, will tell how he got interested in his hobby, archery. He will demonstrate a machine that he has used in obtaining the most precise information known about bows and arrows. Moreover, he will give some demonstrations such as we have not seen since the time of William Tell. On Friday, Mr. Austin H. Clark, of the U. S. National Museum, will appear with his butterflies, telling how he became interested in these and some unusual circumstances in connection with this hobby.

F. C. BROWN,
Chairman of the Committee on the Science Exhibition

SPECIAL ARTICLES

CARBON DIOXIDE AS A FACTOR AFFECTING LAG IN BACTERIAL GROWTH

FOR many years biologists have known that inoculation of bacteria into a fresh, favorable medium is followed by a cycle of population growth and decline. Existent work on the phenomena involved has been extensively summarized in recent years by Winslow[1] and by Buchanan and Fulmer.[2] Usually the cycle includes an initial, lag period of adjustment, a period of rapid constant increase at maximum rate, a period of crisis or stable peak population, and periods of decline and readjustment.

Youth of the mother culture used to start the new population is known generally to decrease the period of lag. Transfer to a fresh medium from a culture already in active logarithmic increase in the same kind of medium often abolishes lag. Lag is also affected by the magnitude of the inoculating dose, the temperature of cultivation and the composition of both new and old media. Most theories to date regard the shortness of the adjustment phase as dependent on some aspect of the biological state of the transplanted cells. Possibilities of prior injury to the cells, of temperature shock, of variable individual cell adaptation, of growth inertia and of required development of essential secretions have been considered, Some writers have favored, as most plausible among biological state theories, the idea that bacteria, like plants, must germinate after a resting period; others have given most weight to the idea that actively growing cells contain "intermediate bodies in the synthesis of protoplasm" which are lost from old cells by diffusion; lag is caused by the time required to restore them to their essential concentration in—or around—the cells after transplantation.

Suggestion that the phenomenon of lag under certain conditions can be explained very simply as the period needed to build up the concentration of CO_2 in the environment—or in the cells—to a value essential for growth is offered in the present report.

In the course of recent studies in this laboratory on the growth curves of bacteria[3] and on metabolic activity of the cells during various population cycle phases,[4] curious influences of aeration on cultivation were noted. Continuous aeration of cultures throughout growth, by air previously freed of atmospheric CO_2 and NH_3, was found in highly nutritious media to prolong lag slightly; on the other hand, in a synthetic medium of lower nutrient value (Dolloff medium: lactose 0.5 per cent., ammonium tartrate 0.5 per cent., dibasic ammonium phosphate 0.002 per cent.) the effect of aeration was to prolong the lag period for a day or more, while unaerated test-tube cultures in the same medium grew well after a lag of not over six to eight hours. In a recent publication of these experiments,[3] the prolonged lag in Dolloff's medium resulting from aeration was interpreted as possibly due either (1) to removal by the air current of some indefinite "essential intermediate bodies in protein synthesis," as mentioned above, or (2) to removal of CO_2 necessary to growth, or (3) to a toxic effect of too much oxygenation in a poor medium.

That CO_2 in the environment is essential to cell growth had been announced as true for over one hundred bacterial strains on solid media by Valley and Rettger in 1926[5] and 1927.[6] A special series of experiments seeking to determine whether CO_2 removal or another of the three possibilities stated above was the causative factor in our results has been undertaken, and the findings are now presented.

The technique, similar to that of the previous growth curve studies,[3] involved cultivation of *Esch. coli* cultures in the Dolloff synthetic medium at 37° C, with record of growth determined at suitable frequent intervals by standard duplicate plate count methods. One purification train, for pressure aeration with CO_2-free air, was exactly as described elsewhere,[3, 7] and included among other units two spiral wash bottles containing, respectively, KOH and H_2SO_4. A second train, for aeration with air from which CO_2 was not removed, was made up from similar units, except that KOH was replaced by water.

In the first and simplest group of experiments, proportionate amounts of the same inoculating cell suspension were simultaneously introduced into three batches of Dolloff medium—one already and constantly thereafter subject to bubbling aeration with CO_2-free air, one subject to aeration with air containing atmospheric CO_2, and the third unaerated. Ammonia was, as is evident, absent from both air currents. The results of three such sets of triple culture

[1] C.-E. A. Winslow, "The Rise and Fall of Bacterial Populations." Chap. vi, pp. 58–83, in "The Newer Knowledge of Bacteriology and Immunology." Edited by Jordan and Falk. U. of Chicago Press, 1928.

[2] R. E. Buchanan and E. I. Fulmer. Chap. ii, pp. 4–62, in "Physiology and Biochemistry of Bacteria." Baltimore, Williams and Wilkins Company, 1928, Vol. I.

[3] C.-E. A. Winslow, H. H. Walker and Margaret Sutermeister, "The Influence of Aeration and of Sodium Chloride upon the Growth Curve of Bacteria in Various Media." *Jour. Bact.*, 24: 185, September, 1932.

[4] H. H. Walker and C.-E. A. Winslow, "Metabolic Activity of the Bacterial Cell at Various Phases of the Population Cycle." *Jour. Bact.*, 24: 209, September, 1932.

[5] G. Valley and L. F. Rettger, "Carbon Dioxide Requirements of Bacteria." *Jour. Bact.*, 11: 78, February, 1926.

[6] G. Valley and L. F. Rettger, "The Influence of Carbon Dioxide on Bacteria." *Jour. Bact.*, 14: 101, August, 1927.

[7] H. H. Walker, "An Aeration Train for the Study of Products of Bacterial Metabolism." *Jour. Bact.*, 24: 169, September, 1932.

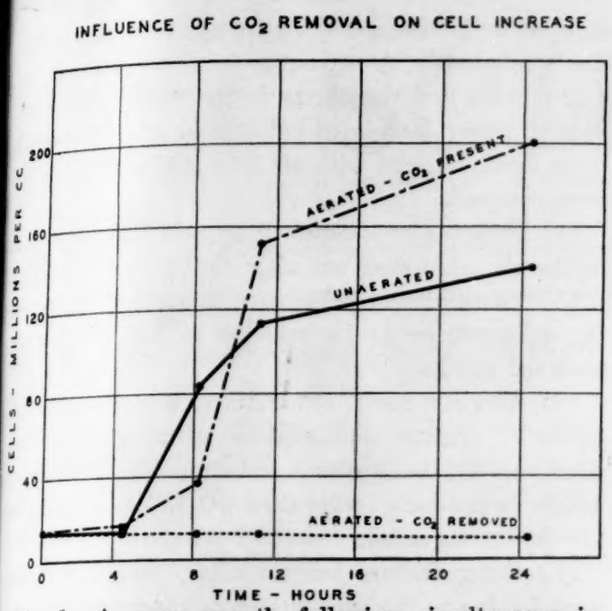

FIG. 1. Average growth following simultaneous inoculation of three portions of medium, one cultivated in a cotton plugged test-tube, one aerated continuously with CO_2-free air and one aerated at a similar rate with air from which CO_2 was not removed.

experiments, no one of which differed materially at any point from the others, have been averaged for presentation in Table 1 and are shown graphically in Fig. 1, where the coordinates represent time and cell numbers.

TABLE I

AVERAGE POPULATION GROWTH UNDER THREE AERATION CONDITIONS

Age (hours)	Millions per cc		
	Condition A	Condition B	Condition C
0	14	14	14
4–5	14	15	14
7.5–9	12	36	82
10.5–12	12	151	113
24–25	10	200	140

A—Three cultures aerated with CO_2-free air
B— " " " " CO_2-containing air
C— " " not aerated

The table and figure clearly reveal that in the unaerated medium good growth was obtained commencing after the fourth or fifth hour; aeration with air from which CO_2 had not been removed resulted in a slightly prolonged lag but gave after 12 hours even better growth; aeration with CO_2-free air permitted no growth in 24 hours. Thus are differentiated the effects of the three aeration conditions on inoculations exposed immediately to them.

Other experiments were now performed wherein three cultures started from the same inoculating suspension were first all inhibited for one day by aeration with CO_2-free air and then subjected respectively to the three conditions above. That is, after 24 hours of aeration with CO_2-free air (no growth having occurred in any bottle) aeration of one culture was discontinued, another was subjected to aeration with CO_2-containing air, and the third was continued under aeration with CO_2-free air for another day. By reference to the experiment shown in Fig. 2[8] it will be seen

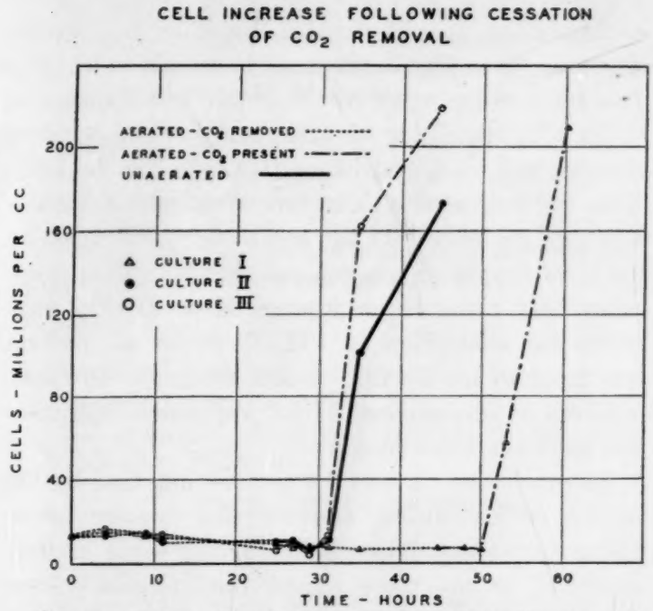

FIG. 2. Onset of growth, following discontinuance of aeration or change to aeration with CO_2-containing air, in cultures previously inhibited for one or two days by CO_2-free aeration.

Culture I aerated with CO_2-free air from inoculation to 45th hour; aerated with CO_2-containing air from 45th to 60th hour.

Culture II aerated with CO_2-free air to 25th hour; unaerated from 25th to 45th hour.

Culture III aerated with CO_2-free air to 25th hour; aerated with CO_2-containing air from 25th to 45th hour.

that the culture (I) kept on CO_2-free aeration for the second day continued its lag accordingly, but the one (II) whose aeration was stopped after the first day underwent in a few hours a normal growth period; so also did the one (III) switched after one day to an aeration train containing no KOH wash bottle (water instead). Finally, after two days of inhibition by CO_2-free aeration, the culture (I) so treated was transferred to the CO_2-containing air train and still proved itself capable of normal growth thereafter. These results appear to show clearly that cessation of removal of CO_2, from cultures previously thereby inhibited, results in normal development, no matter whether aeration is stopped entirely or CO_2 is simply no longer removed from the aerating current.

[8] In the graph, for simplicity, each curve has been continued only as far as the highest count obtained; all cultures subsequently declined in numbers.

A final experiment was performed in order to show that removal of NH_3 by the H_2SO_4 wash bottles, included up to this point in both aeration trains, was not involved in the CO_2 effects noted. To this end, H_2SO_4 was omitted from both trains; all other purification units were left as before. Five cultures were started simultaneously. Three subjected at once to CO_2-free aeration, CO_2-containing aeration, and no aeration, yielded curves similar in all respects to the corresponding ones of Fig. 1. The other two cultures were also, as in Fig. 2, subjected to inhibition by CO_2-free aeration for one day. Then one was transferred to the CO_2-containing air train and one had aeration discontinued; both grew thereafter as in Fig. 2. Likewise, one continued on CO_2-free aeration for the second day prolonged its lag accordingly, but grew on the third day, after aeration was shut off. Thus it appears that presence or absence of an H_2SO_4 wash bottle for absorption of NH_3 from the air current has no effect on the CO_2 results obtained. In short, removal or non-removal of CO_2 appears responsible for the phenomena noted.

In concluding, it may be pointed out that by the method of introducing aliquots of a common inoculating suspension into batches of the same medium subjected to the three chosen conditions—CO_2-free aeration, CO_2-containing aeration and no aeration—most of the factors claimed by earlier workers to be influential upon lag phenomena have been controlled so far as discernment of CO_2 effects requires. Items so controlled include age of mother culture, transfer of inhibitory substances therefrom, size of inoculating dose, nature of both old and new medium, prior injury to cells, temperature shock, variable cell capacity for environmental adaptation, and even particularly favored biological state effects such as the need for a germination period or restoration of postulated intermediate bodies in protoplasmic synthesis. Removal of CO_2, independent from the effect of aeration itself, is therefore the variable studied. Accordingly, we conclude that:

(1) In a synthetic medium of low nutrient value, the lag period of (coli) cultures can be prolonged at will by aeration with an air current purified by passage through a washing train which includes an alkaline, CO_2-absorbent unit.

(2) When parallel cultures are aerated at a comparable rate with air washed through a train similar in all respects, save for the replacement of the alkali by water, normal growth occurs to an even higher degree than is the case in unaerated cotton-plugged test-tube cultures in the same medium.

(3) Cultures inhibited from growth by CO_2-free aeration for a day or more will, when aeration is stopped or is resumed after replacement of the alkaline wash bottle by water, undergo a normal lag of a few hours and then grow in the manner characteristic of newly inoculated cultures in unaerated media or in media aerated with air from which CO_2 has not been removed.

(4) Presence or absence of an acid NH_3 absorbent in the air train does not alter the above phenomena.

(5) There are no differences in nutrient values of the substrate or in its reaction to account for the observed results.

(6) Aeration itself, either through mechanical agitation or through increased oxygenation of the medium, or by the washing out from the medium of metabolic products (other than CO_2), does not account for the results noted.

(7) Other factors being similar, the phenomenon must be due to the substance removed from the aeration current, hence from the medium, by the caustic wash bottle,—CO_2.

(8) Our results, then, tend to (a) Confirm in a fluid medium the necessity of CO_2 for cell growth, which Valley and Rettger demonstrated in solid media; (b) Suggest that the phenomenon of lag may be due largely, if not entirely, to the time it takes the culture to build up the CO_2 content of the medium or of the cells themselves to a value essential for growth; (c) Simplify the philosophy of the lag period by apparently rendering unnecessary the postulation of an essential formation of intermediate bodies in protein synthesis required for growth, other than CO_2.

HAROLD H. WALKER

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